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REPORT OF FRESHWATER MOLLUSKS WORKSHOP 19-20 MAY 1981.(U)
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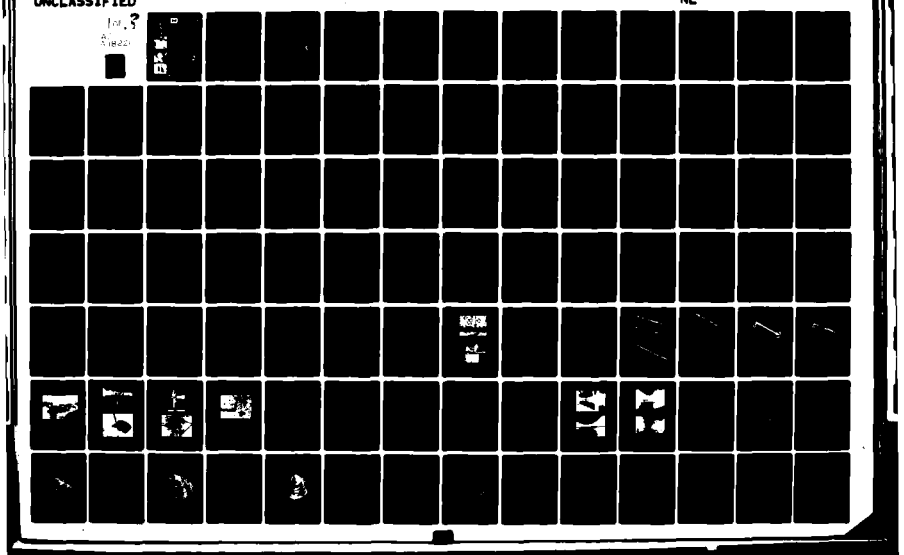

REPORT OF FRESHWATER MOLLUSKS WORKSHOP

19-20 May 1981

By Andrew C. Miller, Compiler

U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

May 1982

Final Report

Sponsored by Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Published by U. S. Army Engineer Waterways Experiment Station
Environmental Laboratory
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Rare animals

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A workshop on Freshwater Mollusks was held on 19-20 May 1981 at the U. S. Army Engineer Waterways Experiment Station (WES). The workshop was attended by representatives from Corps of Engineers District/Division Offices, the academic community, consulting firms, and the commercial shell industry. The purpose of the workshop was to address (a) taxonomy and ecology of freshwater mussels; (b) appropriate sampling methodologies for mollusks; (c) methods to create habitat and/or relocate mollusks; (d) information on the

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20. ABSTRACT (Continued)

above-listed topics available from commercial shell harvesters; and (e) present and past concerns over the endangered species problems. A total of 16 technical papers were presented. In addition, time was allotted for questions and answers and examination of sampling equipment and one structured discussion period was held. The text of the papers presented, the questions and answers following each presentation, and summary reports presented by each discussion group leader dealing with important aspects of the workshop are included.

PREFACE

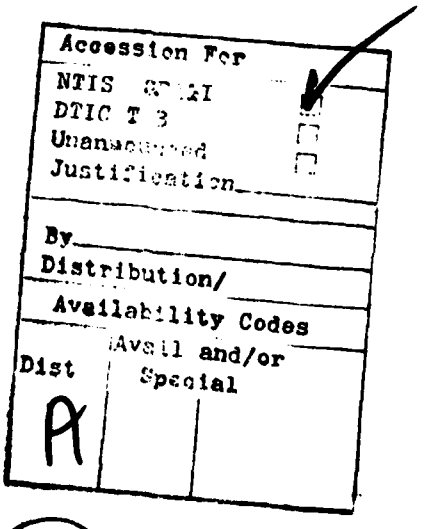
The Freshwater Mollusks Workshop was held 19-20 May 1981 at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. The workshop was part of the Mollusk Study which is part of the Environmental Impact Research Program (EIRP). The EIRP is sponsored by the Office, Chief of Engineers, and managed by WES.

Dr. Andrew C. Miller and Mr. David Nelson, of the Aquatic Habitat Group (AHG), Environmental Laboratory, at WES, organized and conducted the workshop. This workshop was under the general supervision of Dr. Thomas D. Wright, Chief, AHG, Mr. Bob O. Benn, Chief, Environmental Systems Division, and Dr. John Harrison, Chief, Environmental Laboratory. Dr. Miller compiled the papers presented at the workshop into this report.

Commanders and Directors of WES during the workshop and the preparation and publication of this report period were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

The report should be cited as follows:

U. S. Army Engineer Waterways Experiment Station, CE. 1982 (May). "Report of Freshwater Mollusks Workshop," Vicksburg, Miss.



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Yokley, P.	University of North Alabama, Ala.

AGENDA

19 May 1981

0800-0830	Registration
0830-0845	Welcome - Dr. John Harrison, Chief, Environmental Laboratory
0845-0910	Opening Remarks/Workshop Objectives/Status of the Work Unit - Dr. Andrew Miller, WES
0915-0945	The Endangered Species Act of 1973 - Mr. Tom Strekal, OES/FWS, Washington, D. C.
0950-1045	Biology and Taxonomic Difficulties Associated with Freshwater Mollusks - Dr. Arthur Clarke, ECOSEARCH, Inc.
1045-1110	Break
1110-1140	Use of Museums for Assistance in Identification of Mollusks - Mr. Paul Hartfield, Mississippi Museum of Natural Science
1145-1215	Sampling for Mollusks - Mr. David Nelson, WES
1215-1230	Group Discussion
1230-1330	Lunch (Transportation provided to WES cafeteria)
1330-1400	The Distribution and Habitat Requirements of Selected Tombigbee River Mollusks - Dr. Jim Williams, OES/FWS, Washington, D. C.
1405-1425	Habitat Development for Freshwater Mollusks in the Tombigbee River - Dr. Andrew Miller, WES
1430-1450	The TVA Cumberlandian Mollusk Conservation Program - Mr. John Jenkinson, Biologist, Fisheries and Aquatic Ecology Branch, Division of Water Resources, Office of Natural Resources, Tennessee Valley Authority
1455-1515	Relocating *Lampsilis higginsi* in the Upper Mississippi River - Mr. David Nelson, WES
1515-1530	Break
1530-1700	Open Session I
	Group Interaction/General Discussions
	Identification of Mollusks
	Examination of Sampling Gear
	Use of the Literature Search and Retrieval System
	Statistical Problems on Benthic Sampling Programs

20 May 1981

0800-0815	Opening Remarks/Questions
0815-0830	The Higgins' Eye Mussel Recovery Team - Dr. Edward Stern, University of Wisconsin
	Dealing with Endangered Mollusks at Corps of Engineers District Offices
0830-0845	St. Paul District - Mr. Robert Whiting
0850-0905	Louisville District - Mr. John S. Kessler
0910-0925	Detroit District - Mr. Thomas M. Freitag
0930-0945	Mobile District - Mr. Jack C. Mallory
0950-1015	Freshwater Mollusks, The Commercial Approach - Mr. James L. Peach, American Shell Company, Knoxville, Tenn.
1015-1030	Break
1030-1130	Open Session II
	Subgroup Discussion
	Group A - The Academic Community
	Group B - Corps of Engineers
	Group C - Other Agencies, Federal and Non-Federal
1130-1200	Synopsis of Subgroup Discussions
	Group A - Dr. Paul Yokley, Jr., University of North Alabama
	Group B - Mr. Dan Ragland, U. S. Army Corps of Engineers, St. Louis District*
	Group C - Mr. John Pulliam, FWS, Jackson, Miss.
1200-1230	Observations/Concluding Remarks - Mr. John Bushman, OCE, Washington, D. C.
1330-1600	Open Session III (Optional)
	Group Interaction/General Discussion
	Species Identification
	Literature Retrieval
	Sampling Design
	Discussion/Questions
	WES Tour

* Due to unforeseen circumstances, Mr. Dan Ragland was unable to present the synopsis of Discussion Group B. Presentations were made by Eugene Buglewicz, LMVD, and Robert Buselmeier, Ohio River Division.

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic feet per second	0.028317	cubic metres per second
cubic yards	0.764555	cubic metres
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
inches	2.54	centimetres
miles (U. S. statute)	1.609347	kilometres
pounds (mass)	0.4535924	kilograms
square miles (U. S. statute)	2.589998	square kilometres
square yards	0.8361274	square metres
tons (2000 lb, mass)	907.1847	kilograms
yards	0.9144	metres

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

THE MOLLUSK STUDY

by

Andrew C. Miller*

Abstract

The objectives of this Mollusk Study, a two-year project funded by the Office, Chief of Engineers, are to collect information on sampling methodologies, biological and ecological requirements, and habitat creation for selected common and federally listed Endangered Mollusks. The purpose of this meeting is to inform Corps of Engineers District/ Division personnel and other interested parties of the objectives and status of the study and to encourage exchange of ideas and information on mollusks.

Introduction

The Mollusk Study is a two-year project funded by the Office, Chief of Engineers, as part of the Environmental Impact Research Program (EIRP). This study was designed to provide assistance to Federal biologists conducting impact assessments and endangered species coordination and directing contractor studies involved with endangered and common freshwater mollusks. The information obtained by the U. S. Army Engineer Waterways Experiment Station (WES) will be applicable for any area of the United States where freshwater mollusks are found. The Upper Mississippi River System and the Tennessee and Alabama river systems have more than their share of endangered species problems. However, this study, while centering on the federally listed endangered mollusks, will be useful for biologists planning and executing a sampling program for all freshwater bivalves.

On 16 September 1980 an evening meeting was held in Vicksburg, Miss., to discuss directions and objectives of a proposed study on mollusks. Attendees at the meeting were participants in a Fish and Shellfish Habitat Evaluation Workshop. Approximately 25 biologists and planners attended, 23 from Corps of Engineers District offices, and 2 from Division offices. A total of 14 District/Division offices were represented.

Based upon the written and oral opinions expressed during that meeting, the following objectives have been formulated for the Mollusk Study:

a. Collect information on sampling techniques for freshwater

* Research Limnologist, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

mollusks. This will apply not only to the federally listed species, but also the nonlisted organisms. The work on sampling techniques has been subdivided into two tasks. The first task is concerned with methods for the design, construction, and use of various types of mollusk sampling equipment. Included will be information on the applicability of various gear types in different conditions. The second task is to provide techniques for determining adequate sample size and number of samples necessary to satisfy certain objectives. The first task will yield material useful for freshwater mussels; the second task will also provide information applicable to other benthic surveys.

b. Collect and organize biological and ecological data on the federally listed endangered mollusks. This includes data on range, life history, ecological requirements, and identifying features.

c. Analyze techniques used to relocate or create habitat for mollusks. Information developed under this objective will relate to the endangered and nonendangered mollusks as well as certain other benthic species.

The purpose of this meeting is to bring together individuals from the Corps of Engineers District and Division offices, the academic community, private businesses and consulting firms, the U. S. Fish and Wildlife Service, and other State and Federal agencies which have a common interest in mollusks. This workshop will present information on endangered species legislation, the biology, ecology, and taxonomy of the Unionidae, and the manner in which various Corps of Engineers field offices deal with endangered species problems. In addition, WES will provide a complete explanation of the status and direction of this work.

It is not, however, the intent of this meeting to provide only a one-way exchange of ideas and information. Participants are directed to bring forth questions and comments at any time concerning the formal presentations or the direction of the Mollusk Study. To encourage this, on the second day of this meeting, all participants will break into three discussion groups. Based on the backgrounds of those in attendance, the three groups will be the academic community (Group A), Corps of Engineers District and Division offices (Group B), and individuals from museums, private business and consulting firms, the U. S. Fish and Wildlife Service, and other Federal agencies (Group C). By dividing the main body of participants into smaller groups based upon their background and interests it is planned that everyone will have an opportunity to voice his own ideas concerning these subjects.

As of the date of this meeting the Mollusk Study is about one-third complete. Based upon the information received at the workshop, some changes in direction within the scope of the original objectives may be required. The following is a synopsis of progress to date.

Sampling for Freshwater Mollusks

Information on the various types of sampling gear available for freshwater mollusks has been developed by Mr. David Nelson, WES, for this meeting. His discussion includes directions for constructing and using clam rakes, a brail, and quadrate samplers. Information on the usefulness of this equipment in different types of habitat will also be presented. Before the end of this study, the information on sampling techniques will be expanded and formally presented to the field. In addition to detailed plans on how to build and use this equipment, WES will provide information on the proper handling of live mollusks and the necessary procedures for obtaining an endangered species permit.

Statistical Procedures for Benthic Sampling

Determining the proper number and size of samples required is a primary consideration in almost every field survey. This is particularly true with organisms that are very uncommon and found in a habitat that is difficult to see and often hard to sample. A review of the literature on bivalves indicates that the majority of the work has been qualitative and related more to taxonomic or distribution problems than population densities. This portion of the study has been designed to answer some of the questions concerning the proper number and size of samples necessary to meet study objectives. Mere presence or absence of a particular taxa is no longer all the information needed to perform impact analyses. The investigator must be prepared to indicate numbers and provide appropriate confidence intervals.

Benthic organisms are found in three basic distribution patterns: random, uniform, or contagious (Figure 1). Most benthos aggregate in various-size clumps, although on occasion the other two distribution patterns are encountered. It is not unusual to have organisms distributed in complex arrangements that do not fit neatly into one of the three standard patterns.

Freshwater bivalves can be collected by hand, with rakes, or with a brail. However, the only truly quantitative method involves collecting all the organisms within a specific area of the habitat under study. This can be accomplished with a grab sampler (ponar, shipek, etc.) or by delineating a 1-m^2 or a 0.5-m^2 area and collecting all the animals that lie within the confines of the quadrate. If the organisms are not uniformly distributed, chance placement of the sampling device usually yields markedly different results.

Figure 2 illustrates a rapid method of determining how many samples are necessary to provide an accurate estimate of the true mean of a population. In this example a cumulative mean has been calculated after each set of five samples. The mean of the first five samples is

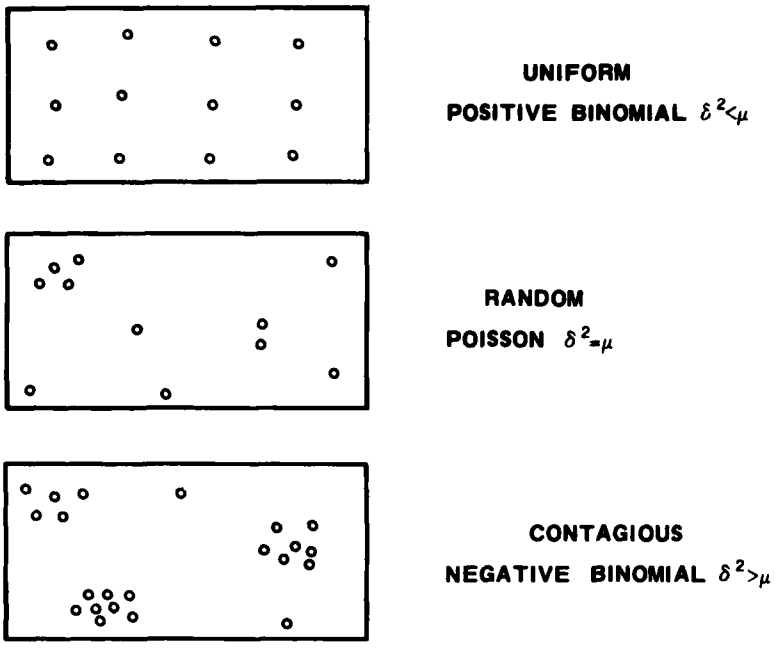

Figure 1. Three possible distribution patterns for benthic invertebrates

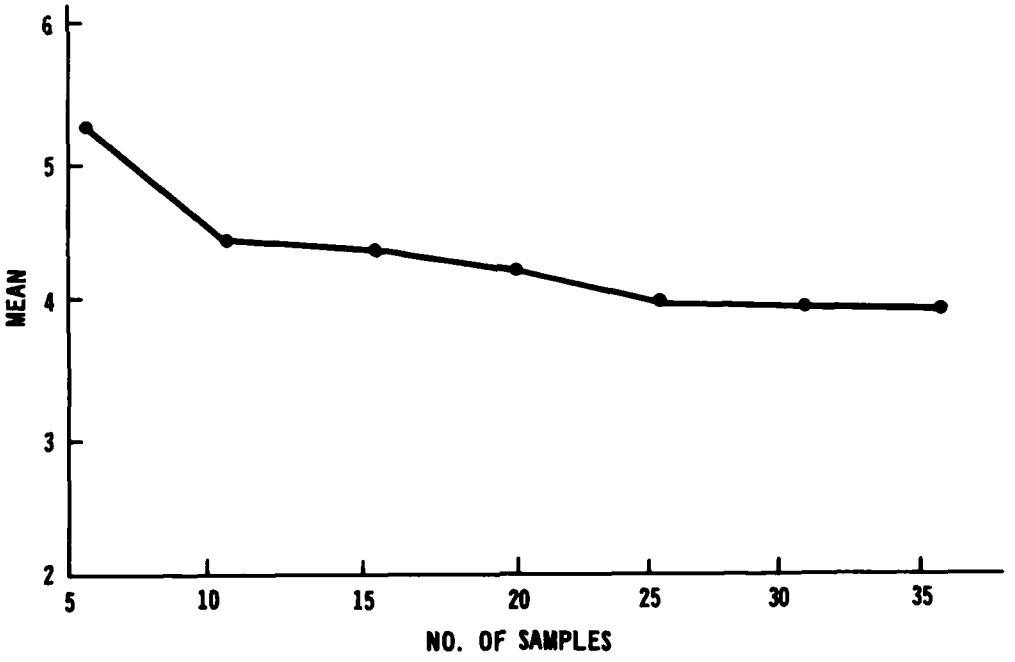

Figure 2. A rapid method for determining sample size

5.4, of the first ten is 4.35, and so on until all 35 samples have been averaged. In this example the line connecting the data points begins to stabilize after 10 and is almost level after 25 samples. In other words, for organisms in this habitat, approximately 10 to 25 samples are enough to roughly estimate the true population mean.

A more elaborate procedure would be to determine exactly the distribution pattern of the organisms inhabiting the area under study. As in the example discussed previously, a pilot survey would be taken and a given number of samples taken. Using the chi squared test, one then determines if the results of the pilot survey compare with known patterns found in the three types of distributions. These theoretical distributions can be calculated by techniques presented by Elliott (1971). These distributions can be developed quickly using a programmable calculator or be determined from published tables (Pearson and Hartley 1966).

One of the approaches taken by WES in this study has been to develop a procedure for simulating the three distribution patterns. Figure 3 is a representation of a clump of organisms in a hypothetical habitat. The "1" represents an organism and the "0" indicates lack of an organism. The computer program which generated this matrix allows the user to determine various aspects of the distribution of organisms.

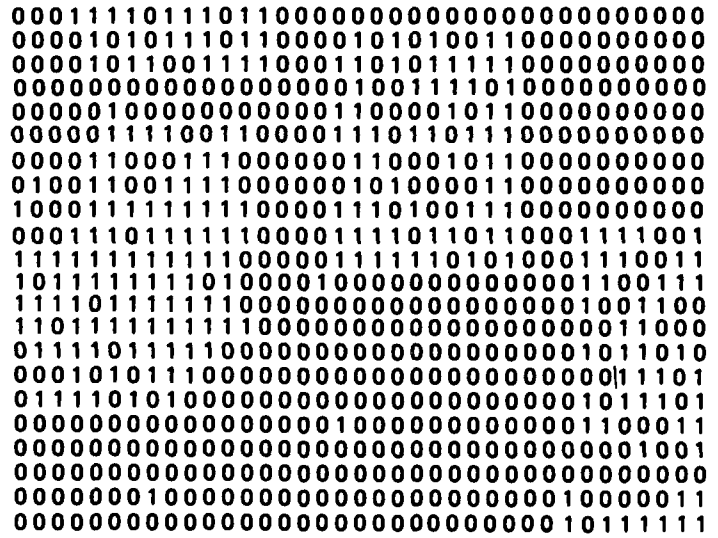

Figure 3. Clusters created by the computer program IMAT

Size of the clumps, background density of organisms outside the clumps, etc., can all be predetermined. After the habitat has been created and saved, a second program "samples" the matrix of "0's" and "1's." This is accomplished by subdividing the area into quadrates of a given dimension. The user then specifies how many samples from the population should be taken. Using random numbers, the computer chooses the

quadrates and counts the "1's" in the appropriate areas. Quadrate size and number of samples taken can be altered as necessary. The program reports on which quadrates were sampled, the number of "1's" in each, and the mean and standard deviation of "organisms" in the matrix.

The purpose of this simulation and sample program is to test the procedures developed for sampling benthic habitats. Obviously, it is easier and cheaper to test these ideas with a computer than in the field. One approach would be to develop a simulation based upon actual field conditions and sample the field and the computer generated data using similar procedures. Future work will involve efficiency studies on the use of a brail. Preliminary studies conducted by the University of Wisconsin's Department of Natural Resources suggest that the brail is roughly one percent efficient in collecting bivalves. Brail sampling is not too dissimilar from using a commercial trawl for marine clams. Statistical problems of estimating population sizes using the latter equipment have been discussed by Russell (1972). Procedures applicable for marine clam sampling may have utility in this study.

A Field Guide to the Endangered Mollusks

WES is gathering information to prepare a field guide to the endangered mollusks. This handbook will be in loose-leaf format and suitable for field, laboratory, or office use. The textual material will be concisely written and include a glossary of technical terms and a literature cited section for those who wish to pursue selected topics in depth.

For each major species treated, the guide will contain the following information:

a. Scientific name, common name(s).

b. Status (endangered, etc.).

c. Identifying features.

d. Confusing species (if present).

e. Habitat.

f. Range in the United States.

g. Remarks.

In addition, each species will be accompanied by color plates which will illustrate anatomical features of both interior and exterior views of each shell. A written description of these identifying features will accompany the color plates. The descriptive material will not

be a taxonomic treatise, nor will it be a layman's definition. If necessary, a paragraph on possible confusing species will be included. This will be written so that the user can decide for himself whether or not he now holds, or has the potential of collecting, the species in question. Separating factors could include one or all of the following: range in the United States, habitat requirements, or specific features of shell morphology. If deemed appropriate, color plates of the confusing species will be included.

The paragraph on habitat requirements will be as specific as possible. In many cases precise information on the ecological requirements for each species is not obtainable. However, when available, this section will include data on water depths, sediment types, water quality tolerances, etc., for the species under consideration. Information on range will be specific without providing a vehicle for exploitation of the resource. Depending on the species, range information will delineate watersheds, names of major rivers, or ranges of river miles where the organism has been collected. The paragraph titled "Remarks" will include any additional pertinent data on the species not previously included.

This guide will specifically treat the federally listed organisms. However, to provide maximum utility for the user it may also treat selected species which are either very uncommon or proposed for listing on the Federal list.

Relocation/Habitat Development for Mollusks

Mr. John Jenkinson, Tennessee Valley Authority, and Mr. David Nelson, WES, presented papers at this workshop concerning this relocation of mollusks. Mr. Nelson discussed relocation of *Lampsilis higginsi* from a proposed bridge construction site at Sylvan Slough in the Mississippi River near Moline, Illinois. Mr. Jenkinson's presentation dealt with a plan to relocate two species of mollusks in the Columbia River, Tennessee. Also, there was a presentation describing a project WES will undertake for the Mobile District in Alabama. This forthcoming work will involve the design and monitoring of a gravel bar habitat for benthic organisms and mollusks to be placed in the Tombigbee River near Columbus, Mississippi. Information from these three projects will be used to develop procedures and guidelines for relocation and habitat creation for mollusks.

Literature Search and Retrieval System

Technical literature pertaining to the objectives of the Mollusk Study will be made available to District personnel and other interested parties by way of an automated literature search and retrieval system.

We are presently storing on the WES computer a ten-line abstract, selected key words, and the complete citation for all publications which relate to the objectives of this work unit. The computer program LITSRC, written in FORTRAN IV, accesses these data files. An individual can obtain bibliographic information describing the habitat requirements, distribution, and available sampling techniques for common, uncommon, and endangered freshwater mollusks. The literature was collected by Dr. Arthur C. Clarke, ECOSEARCH, and WES personnel during this study. Material was obtained from the scientific literature, unpublished reports, and impact studies conducted by Federal agencies. This bibliographic information will have utility in the planning and execution of field surveys, as part of the permitting process, impact analysis, endangered species coordination, and biological inventories for proposed water resource projects.

The bibliographic material is stored in the computer in a sequential data file (Figure 4). Each bibliographic entry requires 16 lines. The first line contains the date of publication and the author's (or authors') name(s). The second and third lines are for the title, the fourth line for the source of publication, and the fifth and sixth lines are reserved for keywords. Ten lines are available for a short summary or abstract of each publication. Prior to running the program, the bibliographic information in the sequential file is rewritten on six random access files. Corrections and additions to the bibliographic data are made to the sequential data file.

The literature on file can be searched for by keyword, author's name, date of publication, or by any word which could appear in the title or abstract. The program first scans all bibliographic data and counts the number of entries present which satisfy the search criteria. After the publications are listed at the terminal, additional searches can be made as needed (Figure 5). It is possible to print only the bibliographic citation or to include the abstract and pertinent keywords with each listing. LITSRC searches for words by breaking or separating character strings into single letters. There must be a letter-by-letter match between a word in the bibliographic material and the work of interest if a citation is to be retrieved. For example "mollus" will match with "mollusk," "mollusca," and "molluscan." However, "mollusk" will not retrieve citations with the work "mollusc" or "mollusca." Use of the program requires only a telephone and computer terminal. LITSRC contains a complete set of directions on how to operate the program which can be printed before use.

Summary

The following papers, presented during the workshop, deal with selected topics concerning freshwater mollusks. Through this meeting, District/Division personnel are obtaining up-to-date information that will assist with problems in permitting, coordination, and impact

BIBLIOGRAPHIC SEARCH AND RETRIEVAL
SYSTEM

10010 DATE, NAME OF AUTHOR(S)
10020 TITLE LINE 1
10030 TITLE LINE 2
10040 SOURCE OF PUBLICATION
10050 KEYWORD LINE 1
10060 KEYWORD LINE 2
10070
10080
10090
10100
10110 } 10-LINE ABSTRACT
10120
10130
10140
10150
10160

Figure 4. An example of the sequential data file for bibliographic information. Line 10170 would be for date, name of author(s) for the next publication

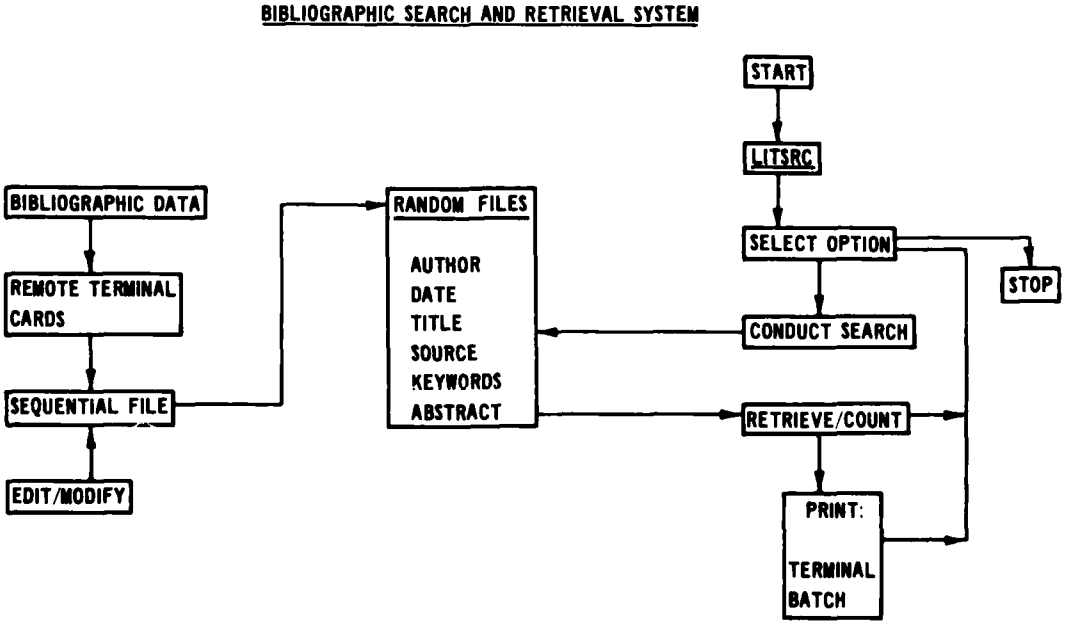

Figure 5. Flow of information in the literature retrieval systems

assessment. All workshop participants have the opportunity to make professional contacts and interact with each other. Finally, WES personnel will benefit from suggestions and comments from District and other biologists actively engaged in studies on freshwater mollusks.

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Elliot, J. M. 1971. "Some Methods for the Statistical Analysis of Samples of Benthic Invertebrates," Freshwater Biological Association Scientific Publication No. 25.

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Russell, H. J., Jr. 1972. "Use of a Commercial Dredge to Estimate a Hardshell Clam Population by Stratified Random Sampling," J. Fish. Res. Bd. Can., Vol 29, pp 1731-1735.

THE ENDANGERED SPECIES ACT AND PROGRAM

by

Tom Strekal*

Introduction

The following information has been transcribed largely from the Endangered Species Program Management Document (PMD) of June 1980 and from the Endangered Species Act of 1973, as amended. It is intended to present background information which led to formulation of the Act, a brief outline of the Act, and an overview of Program organization, function, and direction. There will be only brief mention of regulations, policy, and guidelines which relate to the Office of Endangered Species (OES) and the Program; the reader is encouraged to request such information relevant to listed species and agency actions from the appropriate Service Office (Area, Regional, or Washington). Although the Endangered Species Act sanctions the Endangered Species Program, the Program Manager determined the implementation of the Act.

Program Description and History

The Endangered Species Program, one of thirteen national programs of the U. S. Fish and Wildlife Service, has the mission to lead and coordinate national and Service efforts to achieve the following Service Goal: prevent endangerment and extinction of plant and animal species caused by man's influence on existing ecosystems, and return such species to the point where they are no longer threatened or endangered.

To reach this Service Goal, the efforts of the Endangered Species Program have been organized to achieve three more specific program goals: (a) list qualified species under the appropriate laws and treaties, (b) protect listed species from harmful taking, commerce, and Federal agency actions, and (c) effect the recovery of listed species.

All program objectives, strategies, and guidance contribute to the attainment of these three goals. Ultimate success for this program is the removal of endangered or threatened species from the list because this indicates that their recovery has been accomplished and their future is reasonably secure (see paper by Ed Stern, page 108).

In the past two decades, the Service's endangered species work has expanded from an ad hoc committee of concerned biologists, to a two-person office, to a worldwide cooperative effort. The history of the

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Program's growth can be divided into five distinct phases, each capped by new endangered species legislation and/or a major reorganization of the Program's structure. These periods are:

Pre-1966 activities

The Department of Interior strove to preserve "endangered species" on National Wildlife Refuges and National Parks for many years prior to enactment of endangered species legislation, and provided additional protection through its administration of statutes such as the Fish and Wildlife Coordination Act (16 U.S.C. 661) and the Migratory Bird Treaty Act (16 U.S.C. 703 et seq.). In 1964, the Fish and Wildlife Service organized a Rare and Endangered Committee, which prepared the first U. S. "redbook," Rare and Endangered Fish and Wildlife of the United States, in July 1966. Although no formal legal status or protection was afforded to species included, the committee's efforts served to publicize the plight of selected animals and give official Federal recognition to the problem.

1966-1969 activities

Growing national concern led, in 1966, to passage of the first specific legislation, the Endangered Species Preservation Act, which directed the Service to prepare and maintain an official list of endangered native animals. The Office of Endangered Species, organized in 1967 to administer the Act, initially consisted of two persons. The first list of 78 vertebrates was published in March 1967. Although the Act provided no authority to regulate taking or trading, it did authorize funds for management and research for listed species, and Land and Water Conservation funds were made available to acquire endangered species habitats. The endangered species research effort gained momentum during this period. This had actually begun in 1961 with studies of sandhill cranes, Aleutian Canada geese, and an effort to breed whooping cranes at Monte Vista National Wildlife Refuge in Colorado. This research was shifted in 1966 to the Patuxent Wildlife Research Center in Maryland where a combined field, laboratory, and propagation program was developed.

1968-1973 activities

In 1969, the previous Act was amended by the Endangered Species Conservation Act, which gave the Service new authority to list mollusks and to list foreign species and regulate their import, although there was still no Federal protection for listed native species. Protection was soon provided for a growing number of endangered foreign species, and research on native species continued at Patuxent and its field stations from Puerto Rico to Hawaii. The Secretaries of Agriculture, Defense, and Interior were directed to use their authorities, consistent with their other mandates, to conserve and protect endangered species. The Office of Endangered Species expanded to a staff of 16 with endangered species positions being established in the Regions by the end of

this period. It was also during this period that the concept of a "recovery plan"--a document outlining a step-by-step program for recovery of a species--was conceived and initiated.

1973-1978 activities

A series of events in 1973 substantially molded the program into its present form. Even before passage of legislation at the end of that year, the Service had given new emphasis to the endangered species by making it an item in the Fiscal 1973 budget, and by including it as one of the Service's 13 formal programs when the Program Management System was adopted.

Later that year, enactment of the Endangered Species Act of 1973 (16 U.S.C. 1531-1543) greatly increased the authority and scope of the program. Responsibility for implementing this strong Act was divided between the Secretary of Commerce (for most marine species) and the Secretary of the Interior (for all other species); in addition the Secretary of Agriculture was given responsibility for enforcement of import/export controls for listed plants. Each Secretary had delegated this responsibility to the appropriate agency in his department--the National Marine Fisheries Service, the Fish and Wildlife Service, and the Animal and Plant Health Inspection Service, respectively.

The new Act made profound changes in the listing authority. It recognized "Threatened" species (likely to become endangered) as well as "Endangered" species, thus establishing the possibility of addressing a species' problem before the danger of extinction becomes imminent. It also provided for the listing of any vertebrate or invertebrate, not just members of selected classes as in the 1969 Act, and for listing plants as well, which were not recognized at all in previous legislation. Finally, it provided for the listing of animal populations, not just species or subspecies, making it possible to conserve a species which is in jeopardy in only part of its range.

Public participation was specifically encouraged by the Act. Any person possessing substantial evidence could petition the Service to review the status of listed or unlisted species. In addition to the period for public comment on proposed rule-makings, anyone can request that a public hearing be conducted prior to issuance of a final rule.

Furthermore, any person can bring a civil action in U. S. District courts for alleged violations of the Act; the courts can then enjoin any person or agency (including the Service) from undertaking a harmful action, or compel the Service to apply appropriate prohibitions of the Act.

Section 5 of the Act gave the Service authority to acquire lands for endangered species using the Land and Water Conservation Fund Act of 1965 (16 U.S.C. 4601 et seq., as amended). Lands so acquired will become part of the Service's National Wildlife Refuge System. These

lands can be managed by other Federal, state, or private agencies under a suitable agreement.

Another significant advance was contained in Section 6, further amended in December of 1977, which provided for cooperating states to take a major role in the conservation effort. A state can qualify for a cooperative agreement with the Service if it has state laws substantially similar to the Act, which enable the state to either fully protect and undertake conservation programs for all resident federally listed fish or wildlife or to reach an agreement with the Secretary of the Interior as to which listed fish or wildlife species are most urgently in need of a conservation program. In addition to meeting either of these qualifications, the state must be authorized to acquire land, conduct investigations, and provide for public participation in the State listing process. Entry into a cooperative agreement returns management of resident fish and wildlife to state control, under terms of the agreement and applicable laws and regulations, and makes the state eligible for grant-in-aid funds.

A new dimension of protection was provided by Section 7, which required all Federal agencies to ensure that "actions authorized, funded, or carried out by them do not jeopardize the continued existence of... Endangered species and Threatened species or result in the destruction or adverse modification" of their critical habitat. To ensure compliance, the law further required the involved agencies to consult with the Secretary of the Interior to determine whether a proposed action could jeopardize an endangered or threatened species or its habitat. Since many major projects which could seriously affect endangered species or their habitats have some degree of Federal sanction, Section 7 is considered to be the most far-reaching conservation tool in the Act. Furthermore, Section 7 directed all Federal agencies to use their authorities to develop conservation programs for endangered and threatened species, thereby making endangered species a truly government-wide commitment (see papers (pp 114-162) by District Biologists at this Workshop).

Section 8 of the Act provided for a program of international wildlife conservation. The Service was authorized to use excess foreign currencies accruing under the Agriculture Trade Development and Assistance Act of 1954 (PL 83-480), or appropriated Endangered Species Act funds, to assist other nations in developing conservation programs and training their conservation personnel.

The international section of the Act also addressed implementation of two significant international treaties. The first of these, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (TIAS 8249) established a uniform system for regulation of international trade and introduction from the sea of vulnerable species and their identifiable parts and derivatives.

The Convention directed each party to set up a Scientific Authority to make biological evaluations and decisions, and a Management Authority

to issue permits, make legal and management decisions, and communicate with other party nations. Executive Order 11911, issued in April 1976, named the Secretary of the Interior as Management Authority, established a six-member Scientific Authority to be chaired by the Secretary, and directed him to provide an Executive Secretary and staff support for the Scientific Authority. The Secretary delegated the Management Authority to the Chief of the Federal Wildlife Permits Office (WPO), and chairmanship of the Scientific Authority to the Deputy Associate Director, Federal Assistance. Each of these individuals, as well as the Executive Secretary, was selected and funded by the Endangered Species Program Manager.

The second treaty addressed by Section 8 of the Act was the Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere (56 Stat. 1354; TS 981), also known as the Pan-American or Western Hemisphere Convention. This Convention, negotiated in 1940, technically came into force in 1942, with the Organization of American States as depository. The Act directed the President to designate the appropriate agencies to act on behalf of and represent the United States as required by the Convention. Executive Order 11911 charged the Secretary of Interior with that responsibility, and the President's environmental message of 23 May 1977 proposed that the countries of the Americas take immediate steps to implement the Convention. The Fish and Wildlife Service and the National Park Service share U. S. responsibilities for this Convention. The Convention directs party nations to establish nature monuments for needy species as soon as possible, and to adopt suitable laws and regulations for protection of all native flora and fauna not in specific natural areas. It also addresses migratory birds, including protection of threatened species, and establishes an Annex listing species needing urgent protection, which would be strictly controlled. The Convention requires an import-export permit system similar to that of the Convention on International Trade.

Important changes were made in the degree of protection afforded to listed species under Section 9 of the Act. This section contained stringent prohibitions against all taking and harassment of endangered animals, and against all interstate commerce, import and export, and sale or offering for sale endangered animals and plants, unless conducted under a permit. These permits are available only for scientific or propagation purposes or to enhance the survival of the species.

For a threatened species, the Service can apply any combination of the above prohibitions which could be needed to ensure its survival. This provision has enabled the Service to tailor special rules to the biological and management needs of each threatened species.

Furthermore, a "similarity of appearance" provision allowed the Service to treat a species as endangered or threatened, if it so closely resembles a listed endangered or threatened species that law enforcement agents cannot reasonably distinguish between them.

1978-present

In November 1978 and December 1979, the Endangered Species Act of 1973 was amended (PL 95-632 and 96-159, respectively) primarily to provide increased flexibility and public involvement in protecting imperiled plants and animals and habitats critical to their survival.

The 1978 and 1979 Amendments made several changes in the listing authority provided under Section 4. Any distinct species population segment being considered for protection under the Act is now limited to vertebrate fish or wildlife which interbreed when mature. Critical habitat is defined for the first time (except by regulation) with its determination being included in the listing process concurrently with the species proposed listing. Prior to this, critical habitat was only addressed in Section 7 of the 1973 Act. The Secretary of the Interior must also consider the economic impact and other relevant impacts of specifying any particular area as critical habitat.

A number of other provisions have been incorporated in Section 4. A more involved notification process is now specifically required prior to the listing of species or critical habitat determinations. A "status review" is required prior to preparation of proposals for listing. The proposed regulations must be offered for publication in appropriate scientific journals, and if critical habitat is specified, a general notice including a summary of the proposed regulations and a map must be published in affected area newspapers. In addition, all local government units located within or adjacent to the critical habitat must be notified of the proposed regulation and any environmental assessment or environmental impact statement prepared. Also, a public meeting and hearing, if requested, must be held when critical habitat is proposed. If a species with no critical habitat determination is proposed for listing, a public meeting shall be held when requested (see paper by Jack Mallory, page 159).

The time period for which emergency listing and critical habitat designations are effective (now applicable to both plants and animals) was extended to 240 days. Also, all listings and critical habitat determinations must now be finalized within two years from the date of publication of the proposal or be withdrawn. The Amendments also call for the periodic review--at least once every five years--of all listed species.

A new subsection was added under Section 4 directing the Secretary of the Interior to develop and implement recovery plans for all listed species that will benefit from such plans. This requirement strengthens the Service's prior commitment to develop and implement species recovery plans.

Section 5 of the Act was amended to authorize the use of Land and Water Conservation funds for the acquisition of habitats for listed plants and provided endangered species land acquisition authority to the

Department of Agriculture with respect to the National Forest System. Prior to the 1978 Amendments, habitat acquisition for plants could only occur if the plants were included in the Appendices to the Convention.

Section 6 was expanded to allow the Service to enter into Cooperative Agreements with the States for the conservation of endangered and threatened plants.

The Amendments resulted in a substantial modification to Section 7 of the 1973 Act. Necessary changes in language were made throughout the Act to revise the jeopardy standard under Section 7 from "would jeopardize" to "is likely to jeopardize." The consultation process was strengthened by requiring that a Federal agency with respect to construction projects, request information from the Secretary regarding the presence of any proposed or listed species in the proposed action area. If such species are present, the Federal agency must prepare a biological assessment. Further, once consultation has been initiated (to be concluded within 90 days or a time agreed to by the Secretary of the Interior and involved agency) no "irreversible or irretrievable commitment of resources" may be made by the Federal agency. In rendering a biological opinion, the Secretary of the Interior must detail how the agencies' action would affect the species or its Critical Habitat, as well as suggest "reasonable and prudent alternatives." In addition, all Federal agencies are now required to "confer" with the Secretary of the Interior on any action likely to jeopardize a proposed species.

In order to provide some flexibility in Section 7, an exemption process (involving a Review Board and cabinet level Endangered Species Committee) was included which would, under certain circumstances, permit exemptions from the Act's requirements for Federally authorized activities which cannot be modified to avoid jeopardizing a listed species.

Section 8 was expanded to encourage foreign programs for the conservation of plants as well as fish and wildlife. In addition, a new section was added designating the Secretary of the Interior (acting through the Service) as both the U. S. Management Authority and U. S. Scientific Authority for purposes of the Convention. Also, the 1979 Amendments, while abolishing the existing Endangered Species Scientific Authority (established previously under Executive Order 11911), created an independent International Convention Advisory Commission to advise on scientific policy under the Convention.

Several additional changes were made in the degree of protection afforded listed species. Under Section 9, currently captive-held raptors and their progeny are exempted from the Act's permit requirements. Also, antique articles (except scrimshaw) made from parts of products of listed species before 1830 are now exempted from the Act's provisions. Penalty and enforcement provisions specified under Section 11 have been strengthened by making commercial violators subject to civil penalties without a knowledge requirement as well as assessing criminal penalties

for knowing violations (replacing willful violations) of any provision of the Act.

Endangered Species Act of 1973, as Amended

A brief outline of the Act is included to highlight major points of this legislation which forms the basis for the Endangered Species Program. The reader is encouraged to refer to the complete document for more detail.

I. Sec. 2--Findings, purposes, policies

- A. Finding of Congress
  - 1. Many fish, wildlife, and plant species have value: aesthetic, ecological, educational, historical, recreational
- B. Purposes
  - 1. To provide means of ecosystem preservation
  - 2. To provide program for conservation
  - 3. To meet obligations of treaties and conventions
- C. Policies
  - 1. All Federal Departments shall seek to conserve threatened and endangered species.

II. Sec. 3--Definitions

- A. Critical habitat (CH)
  - 1. Specific areas within geographical area occupied by the species in which are found physical and biological features which:
    - a. Are essential to conservation of the species
    - b. Could require special management consideration or protection
- B. Endangered species
  - 1. Any species in danger of extinction throughout all or significant portion of range

a. Except Class Insecta pests

C. Species

1. Any subspecies and any distinct population segment of any vertebrate species which interbreeds when mature

D. Take

1. To harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in such conduct

E. Threatened species

1. Any species which is likely to become endangered

III. Sec. 4--Determination of endangered and threatened species

A. Factors

1. Present or threatened destruction, modification, or curtailment of its habitat or range

2. Overutilization for commercial, sporting, scientific, or educational purposes

3. Disease or predation

4. Inadequacy of existing regulatory mechanisms

5. Other natural or man-made factors affecting its continued existence

B. Basis

1. Best scientific and commercial (see paper by James L. Peach, page 163) data, and after consultation with appropriate and interested political and private entities

2. Published notice in Federal Register and notification of Governor(s)

a. "proposed species"

3. Allow 90 days for Governors' comments

4. Published summary of all comments and recommendations which relate to action

5. CH requires analysis of economic and other relevant impacts

C. Lists

1. Allows update and revision of Endangered/Threatened list

2. Requires publication of status review of listed or unlisted species in response to petition with substantial evidence

3. A 5-year review required to remove species or change status

D. Protective regulations

1. Taking of resident threatened fish and wildlife species may be allowed in state with cooperative agreement

E. Similarity of appearance

F. Regulations

1. Publication of listing CH in local newspapers

2. For proposed regulation without CH, public meeting, if requested

3. For proposed regulation with CH, public meeting in each state, and public hearing, if requested

4. Allows emergency listing for 240 days

G. Recovery plans*

1. For conservation and protection of listed species

IV. Sec. 5--Land acquisition

A. Acquired by purchase, donation, or agreement to conserve listed species, including plants*

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* Changes mandated by 1978 Amendments.

1. Becomes part of National Wildlife Refuge System

V. Sec. 6--Cooperation with the states

A. Make funding available to qualified states for conservation of listed species, including plants*

1. Two-thirds for individual state's program

2. Three-fourths for 2 or more states with common interest

VI. Sec. 7--Interagency cooperation

A. Consultation

1. To ensure that any action authorized, funded, or carried out by a Federal agency is not likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of CH, unless granted an exemption*

B. Biological opinion

1. Result of consultation

2. Details how agency action could affect species and/or CH with reasonable and prudent alternatives*

C. Biological assessment

1. Agency required to identify endangered or threatened species which could be affected by action

D. Limitation on commitment of resources

1. Prohibits "irreversible or irretrievable commitment of resources"*

E. Endangered species committee for exemption*

1. Composed of 7 members--requires vote of 5

2. Can grant exemption to agency action, if

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* Changes mandated by 1978 Amendments.

a. No alternatives to action

b. Benefits greater than alternatives

c. Action of regional or national significance

d. Establishes mitigation and enhancement measures

3. Can permit extinction of species

VII. Sec. 8--International cooperation

A. Encouraged by funding, personnel, international agreements, and law enforcement activities, for plants as well as animals*

VIII. Sec. 9--Prohibited acts

A. For endangered fish and wildlife, it makes it unlawful to

1. Import to or export from U. S.

2. Take within U. S. jurisdiction

3. Take upon high seas

4. Deliver, receive, carry, transport, or ship in interstate or foreign commerce

5. Sell or offer for sale in interstate or foreign commerce

IX. Sec. 10--Permits

A. Can permit any actions prohibited by Sec. 9

1. For scientific purposes

2. To enhance propagation or survival

Important Resource Problems

The development of specific goals and objectives is essential to

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* Changes mandated by 1978 Amendments.

any planning process. The basis for establishing goals and objectives is to define what is important to an organization. Fish and wildlife and their supporting ecosystems are of obvious importance to the Fish and Wildlife Service. But, given limited dollars and work force, it becomes necessary every year to limit program activities to protect, conserve, and enhance those fish and wildlife resources of the greatest importance and concern to the Nation. Important Resource Problems (IRP's) define those fish and wildlife resources with significant problems in specific geographic areas. The Directorate of the Fish and Wildlife Service, using a series of ranking factors and relative weights of importance, have ranked the IRP's. These IRP's will be used as a focal point and planning tool for development of Servicewide goals and objectives in the appropriate Program Management Documents. It should be understood that IRP's will never totally replace administrative priorities or totally dictate budget decisions.

Important Resource Problems will identify areas of emphasis, but this does not mean that the Fish and Wildlife Service will necessarily cease to work on those problems in geographical areas that are not included in the list. Work on many of these problems can be nondiscretionary and the Service will continue to incorporate that activity into its programs. However, IRP's will provide guidance and rationale for: new initiatives, budget justifications, reprogramming decisions, and dollar and workforce allocation. Most importantly, IRP's will provide the mechanism for increasing the effectiveness of the FWS programs to protect, restore, and enhance fish and wildlife resources of greatest importance by focusing manpower and dollars on areas of concern. The following IRP's relate to freshwater mussel conservation.

National Rank	Resource and Area Call Word (IRP No.)
65	Endangered Mollusks and Finfish - Tennessee River Basin, Va. (414,509)
66	Endangered Mollusks - Upper Mississippi River (311)

Within the Office of Endangered Species, the Branch of Biological Support has the responsibility for listing species as required in Section 4. All but one of the 25 endangered freshwater mussel species were listed on 14 June 1976 (41 FR 24062), and had been included in Appendix I of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES); the tan riffle shell was listed on 23 August 1977. Consultation (Section 7) and recovery plans (Section 4(g)) are the primary responsibilities of the Branch of Management Operations. A high proportion of consultations involving mussels relate to permits; efforts have been made to standardize recommendations in order to ensure consistency and provide adequate protection for listed species.

Increased responsibility for listing and consultation activity has been delegated to the Service's Regional, Area, and Field Offices. This

has been done to involve the endangered species staff more closely with agency actions and to improve communication with personnel from other agencies.

Related Programs

The Endangered Species Program is intrinsically related to all Service programs and most organizational units. Each of the resource-defined programs of the Service has an obligation to prevent species within their respective authorities from becoming threatened or endangered. When endangered or threatened species are delisted, management responsibilities are transferred to the appropriate Service program or other Federal agency. Specific discussion of certain relationships with Service programs and organization units follows.

Mammals and Nonmigratory Birds Program (MNB)

This program administers and funds most marine mammal activities for the Service under provisions of the Marine Mammal Protection Act; activities on endangered or threatened marine mammals are administered by the Endangered Species Program. MNB also shares funding of law enforcement efforts, and regulates the importation of injurious wildlife, helping to protect endangered species habitats from the invasion of potentially harmful exotic species.

Migratory Bird Program (MB)

This program shares responsibility with MNB for law enforcement efforts and import-export control at U. S. borders. MB, under its responsibility for developing hunting regulations, will consult with the Endangered Species Program to assure that the shooting of migratory game birds does not jeopardize the continued existence of any endangered or threatened species.

Federal Aid Program

This program administers the allocation of Endangered Species Act grant-in-aid funds to states which have cooperative agreements. Federal Aid also allocates Federal aid in Fish and Wildlife Restoration (Pittman-Robertson and Dingell-Johnson) funds to states, some of which are used for nongame work. Project approval and review is accomplished by the Division of Federal Aid with assistance from the Office of Endangered Species.

Animal Damage Control Program

This program may carry out necessary control of animals that compete with or prey on endangered or threatened species.

Interpretation and Recreation Program

This program conducts programs to illustrate the interpretion of the ecology of species inhabiting Service lands, including endangered or threatened species.

Office of Endangered Species (OES)

This office has the responsibility for preparing and reviewing listing and critical habitat proposals and final actions at the direction of the Program Manager; it reviews states' qualifications for cooperative agreements; it oversees and conducts Section 7 consultations; it reviews recovery plans and recommends any changes necessary to the Program Manager; and it generally serves as staff to the Program Manager for the direction and implementation of the Program.

Division of Ecological Services

This agency contributes to the protection of endangered and threatened species habitats through its mandated review of federally funded or licensed water development projects, permits, and Environmental Impact Statements as they pertain to all fish and wildlife resources and associated habitats.

National Fish Hatchery System

This system maintains and operates facilities for holding and propagating endangered or threatened fishes.

Division of Law Enforcement

This division is responsible for the enforcement of prohibitions on taking and interstate commerce under Section 9 of the Endangered Species Act and control of importing/exporting under both the Act and the Convention on International Trade (except for plants).

Division of Realty

This division reviews the endangered species habitat and lands identified in recovery plans and proposed for acquisition, appraises tracts for acquisition, prepares necessary supporting documents, and carries on negotiations to acquire those tracts.

National Wildlife Refuge System

This organization manages and protects those listed species and their habitats under Fish and Wildlife Service jurisdiction.

Research

This organization, with its divisions of fishery and wildlife

ecology and through the Cooperative Fishery and Wildlife Research Unit Program, conducts in-house research activities on listed species in their natural habitats and in captivity, develops techniques for those management procedures recommended in recovery plans, propagates listed species in captivity, when necessary administers research contracts, and provides taxonomic expertise on specimens taken in law enforcement cases when requested.

Federal Wildlife Permit Office

This office administers the permit requirements of the Act and the Chief of the office serves as Management Authority for the Convention on International Trade.

International Affairs Staff

This group administers the Excess Foreign Currency programs for listed species, manages educational programs for foreign nationals, and coordinates international relations involving conservation of plants and animals.

Public Affairs

Public Affairs issues Endangered Species news releases and other informational materials and produces Endangered Species TV and radio spot announcements.

Office of Extensive Education

This office, and designated contact personnel in the Regional and Area Office, will provide the linkage between the Fish and Wildlife Service and educational systems in the Land Grant Universities and Sea Grant Universities to use these systems in accomplishing the Endangered Species Program objectives.

Endangered Species Program Development Staff

Formerly a part of OES, this group carries out national planning, budgeting, and evaluation for the Endangered Species Program.

Office of Scientific Authority

This office is the Scientific authority for the Unites States under CITES.

Conclusion

According to the Program Manager, as stated in the Endangered Species Program Management Document, all Federal agencies have clear responsibilities under the Act, and state fish and game agencies have

an urgent opportunity and a continuing invitation to participate as fully as their resources and authorities will allow. Agencies whose primary mission is managing lands or regulating wildlife or plants must develop active programs for listed species within their jurisdiction and play a key role in both the recovery of species and their management after delisting. Other environmental regulatory agencies must incorporate the ecological needs and tolerances of listed species in all of their rule-making and permit-issuing processes. Economic and social development agencies must, at the very minimum, ensure that their actions do not compromise the existence of listed species or their habitats, and, further, contributions of their own particular expertise and resources to solutions of endangered species problems are both authorized and mandated by the Act.

The sum of all of these efforts must be a broad national conservation program which will successfully prevent the further decline of species and restore them to good health. Equally important, this program must provide safeguards to ensure that recovered species do not reenter the cycle of decline. Where adequate authorities do not presently exist for the monitoring and management of delisted species, new ones must be sought.

In a world where what we do will be approved by some and disapproved by others..., there is but one solution - do what is biologically right for the resource; do what is legal; and do whatever is done with as much public participation as possible.

THE RECOGNITION OF ECOPHENOTYPES IN UNIONIDAE

by

Arthur H. Clarke*

Summary

Studies on *Anodonta*, *Alasmidonta*, *Obovaria*, and *Pleurobema*, in which some correlations between ecology and morphology are believed to exist, are discussed. In cases where ecologically related morphological (ERM) features vary in a continuum, the various morphs are interpreted as ecophenotypes. In cases where discrete groups of individuals may be recognized on the basis of ERM features, and no intergrades can be found even in areas of sympatry, it is believed that evolution has progressed farther, i.e. that previously existing morphoclines have subsequently been fragmented by the development of barriers and that these isolated groups have evolved genetic isolating mechanisms and now persist as distinct species after the barriers have been removed. The data suggest that the former cases are characteristic of young, immature biomes and that the latter are characteristic of older, more mature biomes.

Introduction

Some groups of mollusks contain nominal species which are so difficult to differentiate that only a few experts are able to distinguish them. The freshwater families, Pleuroceridae, Physidae, and Sphaeriidae, and in the Unionidae the genera *Fusconaia*, *Pleurobema*, *Elliptio*, and *Anodonta* are in this category. Such an appraisal is clearly justified in *Physa* and in *Pisidium* in which the characters have been shown to be cryptic. In some cases, however, especially when studying the faunas of recently glaciated parts of the Northern Hemisphere, one suspects that the reason that most workers have difficulty in making identifications is that there are more nominal species recognized in the group than are justified. The reason that an unnamed mollusk cannot confidently be assigned to nominal species A, B, or C may be because A, B, and C are all the same species.

During the past 200 years, most species of freshwater mollusks in North America and in Europe have been redescribed under several different names. A frequently observed reason for this resides in the inherent characteristic of many species of freshwater mollusks to exhibit distinct phenotypes when living under divergent ecological conditions. When a research worker attempts to evaluate the taxonomic status of similar nominal species, he must address this problem, and he must decide, on the basis of available evidence, whether he is dealing with different

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species or with ecophenotypes of the same species.

Approaches to solutions to such problems vary among workers in the field. Methods involving immunology or electrophoresis can reveal genetic similarities and differences with great precision and objectivity, as the recent landmark paper by Davis and Fuller (1981) clearly demonstrates. The question of whether particular character states are genetic or ecophenotypic can often be answered satisfactorily, however, by using more conventional comparative methods that do not rely on the facilities of a molecular genetics laboratory. The conclusions that can be derived from comparative methods can often be reliably tested by electrophoretic techniques and such testing, if feasible, is clearly desirable. When dealing with endangered species, however, the collection of sufficient live material for electrophoretic studies will probably be unwise, impossible, or against the law.

Comparison of Intrinsic and Extrinsic Attributes

I have found the following straightforward procedure useful for evaluating the taxonomic status of similar nominal species and subspecies of freshwater mollusks from Canada and the northern Unites States.

a. Using all of the population samples that are available, quantify the variation in all morphological attributes that appear to be significant and statistically summarize the results for each sample.

b. Using all of the data associated with the samples, characterize and list quantitatively, or at least qualitatively, all apparently useful ecological attributes (e.g. substrate particle-size distribution, water temperature characteristics, water chemistry data, etc.) and statistically summarize them where appropriate.

c. Using applicable statistical or graphic techniques, compare the morphological attribute summaries with both the ecological attribute summaries and with geographical orgins (by river systems if appropriate), and look for correlations. If morphological-ecological correlations are absent and morphological-geographical correlations are present, we are probably dealing with different taxa. If morphological-ecological correlations are present and morphological-geographical correlations are absent we are probably dealing with ecophenotypes. If morphological-ecological correlations and morphological-geographical correlations are both present, or if they are both absent, the problem cannot be resolved satisfactorily by this method alone.

It is often necessary to collect the population samples and to measure the ecological attributes personally because museum collections are ordinarily inadequate for this purpose. Much valuable, year-round water quality data are available from the U. S. Geological Survey (see Briggs and Ficke 1977). Of course, for statistical comparisons to be reliable, proper sampling and analysis procedures must be followed. These are described in many textbooks on statistics. For useful non-parametric methods, such as the Spearman Rank Coefficient, see Siegel (1956).

The general procedure outlined above is not new but is seldom used in malacology. I believe that there is an obvious need for more objective approaches in taxonomy, however--approaches in which the bases for conclusions are clearly described and justified.

A few studies of Unionidae have been published in which intrinsic and extrinsic attributes of populations are compared. In a revision of *Anodonta* in the Canadian Interior Basin (Clarke 1973), involving 30 population samples, 10 morphological features of the shells were measured or scored by comparison with arbitrary standards. These values were then compared with water body types (large lakes, small lakes, large rivers, small rivers, and backwaters), substrate quality (gravel, sand, mud, clay, and combinations of these), and geographical location of the sample sites. Good correlations of morphology with ecology were found in regard to the relative position of the unbones (more centrally located in populations from large lakes with sand bottoms) and in regard to the percentage of specimens that have green or greenish periostracum (positively correlated with mud substrates). Good correlations of morphology and geography were found in regard to the kinds of beak sculpturing (double-looped versus single-looped), the relative position of the umbones, and the relative obesity, and a fairly good correlation of the relative height with the geographical location was also observed. The geographical correlations were considered sufficient for the recognition of two subspecies of *Anodonta grandis* (Say) within the research area, and for other conclusions about zoogeography. Similar procedures were also used in that monograph for evaluation of attributes in *Lampsilis radiata* (Gmelin) and in the gastropods *Lymnaea atagnalis* (L), *L. atkaensis* (Dall), *L. catascopium* (Say), and *Helisoma anceps* (Menke).

In a more recent study, a monograph on the Tribe Alasmidontini (Clarke, 1981), population samples of the *Alasmidonta undulata* complex from 18 river systems throughout its geographical range (Nova Scotia to Florida in eastern North America) were measured or scored for eight shell characters. Those values were then compared with average values of water hardness and with water temperature characteristics. A good correlation was found between relative shell weight (weight ' volume) and a coefficient (Q_{ht}). This coefficient is defined as water hardness (ppm $CaCO_3$) divided by degree-days in excess of a threshold temperature of 40°F. High values of water hardness and low temperatures favored the production of thick shells, and low values of water hardness and relatively high temperatures favored the production of thin shells. All

coastal stream habitats south of Virginia were found to have water of low hardness and high temperature and also to produce the specimens with the thinnest shells, so correlations of morphology and ecology and of morphology and geography were both present. Detailed comparisons of anatomy and glochidia of northern and sourthern populations revealed no additional differences, so a decision was reached that the nominal species *Alasmidonta triangulata* (Say) is probably a low-hardness, warm-water ecophenotype of *A. undulata* (Say), and that the nominal species *Alasmidonta swainsoni* (Sowerby), believed to be based on specimens from the St. Lawrence River System, is a high-hardness, cold-water ecophenotype of the same species. Further studies in other Anodontine groups have indicated that the relationship between relative shell weight on the one hand and water hardness and temperature on the other is not universal, e.g. some species of *Lasmigona* appear to have rather thin shells regardless of water quality.

Problems Involving Endangered Species

Late in 1980 we were asked to search for *Obovaria leibi* (Lea) in a part of Lake Erie in which a dredging disposal facility was scheduled to be built. *O. leibi* is listed on the state endangered species list there, and its presence in the area probably would have stopped construction of the facility. Many normally riverine species of Unionidae occur in that part of Lake Erie, and all populations of these species are slower growing and smaller in maximum size than those in favorable river habitats. No living specimens of *O. "leibi"* were found in the critical area, but empty shells were relatively common on the beach. It was clearly apparent that they too represented slow growing, stunted specimens of a normally riverine species, in this case of *Obovaria subrotunda* (Rafinesque). *O. leibi*, therefore, should not have been listed as an endangered species since it is not a separate entity.

Some evidence suggests that the status of some species, now included in the Federal Endangered Species List, should also be reviewed. One such case involves *Pleurobema plenum* (Lea). According to the literature, a morphocline exists which includes *Pleurobema coccineum* (Conrad), *P. cordatum* (Rafinesque), *P. plenum* and *P. pyramidatum* (Lea). The four taxa are reported to have occurred, at least up to a few decades ago, in a more-or-less distinct headwater-to-mouth sequence in a few still healthy rivers in the Ohio River System. The species are characterized chiefly by a progressive shift of the umbones from a subcentral position to a near-terminal anterior position, an increase in height relative to length, the development of a radial sulcus on the posterior slope in *cordatum, plenum*, and *pyramidatum*, and some differences in nacre color. In the Green River at Munfordville, Kentucky, empty shells of all of these taxa are found together, however, and this has led one recent investigator (Stansbery 1965) to conclude that they are distinct species.

Clear-cut headwater-to-mouth morphoclines, principally involving

increases in relative obesity, have been reported to occur in the thick-shelled genera *Amblema, Quadrula, Fusconaia, Lexingtonia, Pleurobema, Cyclonaias*, and *Obovaria* (Ortmann 1920 and Goodrich and van der Schalie 1944). More than 50 years ago, European authors (Israel 1913 and Geyer 1927) were also aware that in muddy habitats the species of *Unio* became arcuate, thus shifting the thicker and heavier portions of the shell (umbones and hinge plates) to a more central anterior position. Such a shift acts to decrease the tendency for the mussel to "roll over on its back" in the substrate, an event which would bury its incurrent and excurrent openings in the mud. This phenomenon has not been reported in North American species, but it seems reasonable that it might occur here.

Ortmann (1920) also reported a tendency for a few highly sculptured species (*Quadrula cylindrica* (Say) and *Dromus dromas* (Lea)) to exhibit decreased sculpturing in upstream populations. The whole question of the function of sculpturing in unionids deserves additional attention, I think, in reducing the tendency for them to tip over or to sink in soft substrates. For example, the heavy, diagonal ridges on the shells of *Amblema plicata* (Say), *A. neisleri* (Lea), *A.* ("*Megalonaias*") *gigantea* (Barnes), and *A.* ("*Plectomerus*") *dombeyana* (*Valenciennes*) in the Ambleminae and of *Arcidens confragosus* (Say) and *A. wheeleri* (Ortmann and Walker) in the Anodontinae are particularly well suited to provide stability because they are oriented in precisely the best direction to maintain the mantle openings in an upright, exposed position. The development of a sharp posterior ridge in *Lampsilis ovata* (Say) and of radial posterior ridges or sulci in other downstream species may serve a similar function. Highly sculptured species also have large surface areas which are clearly advantageous for promoting stability in soft substrates. One common mud-inhabiting species, *Tritogonia verrucosa* (Say), has combined all of these sculptural features to a remarkable degree.

It is, therefore, tempting to conclude that the smooth-shelled taxa *Pleurobema coccineum, P. cordatum, P. plenum,* and *P. pyramidatum*, for example, are probably all ecophenotypes of a single species which occupies firm, moderately firm, and soft substrates in a headwater-to-mouth sequence. Such a conclusion, however, might be dangerously incorrect and might bring about disastrous consequences if it was further concluded that since *P. cordatum* is not endangered, its presumed ecophenotype *P. plenum* was also not in jeopardy and did not deserve protection.

Dillon (1981) has recently discussed the genetics of *Goniobasis proxima* (Say), a snail which inhabits small streams in North Carolina. Its populations are exceedingly long and narrow and they are susceptible to measurable interruptions in gene flow between portions of those populations when temporary barriers occur. A similar phenomenon may well exist in the Unionidae, although barriers, to be effective, would need to be much larger and of longer duration. The Green River and many other rivers in Kentucky and Tennessee, for example, flow in deeply cut valleys and are obviously ancient streams. There appears to have been more than sufficient time for species to have evolved morphological-ecological

clines, perhaps in a headwater-to-mouth sequence, and for barriers to have developed which would isolate portions of those clinal populations for sufficient time to enable those isolates to differentially accumulate mutations and thereby to become distinct species. Such species, of course, would maintain their individual genetic integrities even after the barriers ceased to exist.

My recent field experience in the Green River has convinced me of the correctness of the views of those workers who believe that *Pleurobema coccineum, P. cordatum, P. plenum*, and *P. pyramidatum* are all distinct species. The Green River is now seriously impacted by cold, silty water, and its fish and mussel faunas have both been drastically depleted. A few specimens and many recently-living subfossil specimens of these four taxa may still be found there and intermediate morphs do not occur. There is, therefore, no evidence of recent gene flow between them, and they must therefore be regarded as discrete species.

Conclusions

The evidence reminds us that one cannot necessarily apply completely those taxonomic or ecological principles that serve well for understanding an immature biome, such as in northern North America and in northern Europe, to studies on a much more mature biome, such as that of the southeastern United States. In efforts to distinguish between distinct species and ecophenotypes, it is always important to consider and to compare many features of morphology and ecology. If ERM features are identified, however, one must still search for evidence of gene flow between the various morphs. If ERM features vary clinally, i.e. in a continuum, the morphs are probably ecophenotypes. This situation appears to be characteristic of young, immature biomes. If discrete groups of individuals may be recognized on the basis of ERM features, and no intergrades occur even in areas of sympatry, it is probable that evolution has progressed farther and the morphological groups now represent distinct species. This condition appears to be typical of older, more mature biomes. The problem of distinguishing between closely related species and ecophenotypes is not always simple, especially when dealing with several taxa which occur in biomes that have achieved different levels of maturity (Clarke 1979), but an incorrect solution to the problem may have important biological and economic consequences.

Acknowledgments

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THE USE OF MUSEUMS FOR ASSISTANCE IN THE IDENTIFICATION OF MOLLUSKS

by

Paul D. Hartfield*

The Purpose of Systematic Collections

My objective is to describe the use of museums for the identification of mollusks. The word "museum" in this discussion includes all institutions that maintain systematic collections and make them available to the scientific community. A systematic collection is one in which the species are organized according to their presumed natural relationships with each other.

The process of the naming of organisms had its roots with the origin of man. The need for a process of identification was to distinguish beneficial plants and animals from harmful ones. However, as our uses of the environment increased, our relationship with it became more complex and the need for organizing our knowledge of the biological world became evident. From this need grew the discipline of systematics.

As systematics became a vital tool of biology, it was only natural that collections would become the storehouse of this discipline. Other than their political and recreational uses, they were needed to compare newly encountered organisms with previously identified material. It is an old adage in the museum world that a picture may be worth a thousand words, but a specimen is worth a thousand pictures.

As groups of organisms were divided and classified, and the species' lists grew, systematists began to find that the more they knew of the group with which they worked, the better classifications they could develop. This led to increased research into ecology, behavior, biogeography, and evolution, and today there is as much use of collections in these areas as in systematics.

The purpose of identifying and classifying organisms has changed to some extent quite recently. It is no longer enough to distinguish between beneficial and harmful organisms. The lines between these two groups are not as clearly drawn as they were in the past. It has become apparent that man can do about as much damage to his environment as it can do to him. It is also true that we are losing unique species before we can determine their relationship and potential uses to us. Systematic collections can be used to document many of the changes man has brought about and maintain examples of species now extinct.

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Collections store bits of information much as a computer does. Each bit contains information about a certain point in time, a particular point in space, and an organism which occupied both. Considering that regional museums may have hundreds of thousands of these bits, and national museums have millions, you can realize their potential to the scientific community. For example, a good research collection will have specimens of hibernating or migrating species; it can consolidate examples of species that may range over several thousand square miles and offer examples of widespread populations; it may even have successive generations of the same populations; it may provide specimens of rare, endangered, or extinct species; it can offer a means of mapping distributions; and it can be used to identify areas of species diversity. Collections are maintained as a national and regional resource for the use of all fields of biology and can save a great deal of time and travel as a first step in all biological research.

Using the Museum as a Resource

The mollusk collection resources of North America are extensive. In 1975 they were estimated at 72 million specimens in 38 collections (Solem 1975). There are literally thousands of smaller and private collections which have not been counted.

The most obvious use of this resource by the individual collector or researcher is for the identification of specimens, and most museums believe that this is a service that they should provide. The demand, however, is far greater than they can properly handle, especially during this time of environmental impact statements, assessments, and other types of biological surveys. It has also been determined (Solem 1975) that there were only 26 malacological curatorial positions, and 15 of these were at only 6 institutions, so several of the largest collections are without curators or supporting staff. Since a portion of these curators are marine specialists, there are few choices of where to send specimens for identification. The few that remain are generally inundated with requests, and, as a result, most have begun to charge state and federal agencies and consulting companies, especially on large quantities of specimens and for information requests above and beyond identification. Most try not to charge private individuals unless that request is part of a funded study.

Another obvious use of collections is to verify previously identified specimens. Most museums have facilities for visiting scientists, and with a few prior arrangements you can compare your material with other specimens in a reference collection. This works quite well if you have a few environmental oddities and are working with a museum collection with good series arrangements. Along this same line, if you have any specimens you have not been able to identify, a good systematic collection is of great value, and you might get some professional advice and opinions from the staff.

Perhaps the most significant way in which collections can be used is for information storage. If you donate your material to a museum it will eventually be cataloged into the collection. This ensures the survival of the specimen and the information you have obtained and adds another bit of information to the collection resource.

It is also a good idea to make prior arrangements before visiting a museum for this type of work. Common and large collections may be put into a backlog and could take years to be cataloged. Rare, endangered or unusual specimens will usually be processed quickly. Specimens from little known areas (such as Mississippi) or from areas that are to be altered (such as a stream to be channelized) are also more likely to be processed. Be aware, however, that backlog is a problem in practically every collection.

Using the Collection

There are few restrictions on using public collections. Access to university and private collections may be more difficult, but if you can show a need you should be able to gain access. There are a few courtesies to remember, whether you are sending material for identification or using the collection. As stated earlier, prior arrangements are always helpful. If you plan to use the museum collection, it is always important to have permission before going to the expense of traveling any distance, and the curator or curatorial assistant may be able to assist if they are expecting you. If sending specimens, negotiate terms in advance. You may find that donating material will reduce any charges that may be made. It may also help you to know while collecting that well preserved specimens with soft parts are more valuable than shells alone, and fresh valves are worth more than weathered material.

Whether you send your material to a museum or identify it yourself, take the time to clean your specimens. This usually has to be done before a positive identification can be made, and cleaning in advance may save time and money.

If you are donating specimens, make sure that you provide complete basic collecting data including date, location, and collector. Many collectors tend to code their material, and there is nothing worse than trying to break someone else's code. Any other ecological data you may be able to add is always appreciated and adds to the value of the specimen.

If you do not intend to donate your *entire* collection, it is a good idea to sort and arrange your material into a reference collection. If you have any doubt whether a specimen fits into a series, start a new one. You can then send or take several examples from each series for identification.

As stated earlier, collections are maintained as a public and scientific resource. Donating your collections adds significantly to this resource and could save public expense in the future. There are museums in every part of the country that may be able to help you with the identification of mollusk collections (Table 1). For additional information on the use of museums as a resource, see Stansbery (1970) and the Systematic Biology Collections of the United States (1971).

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Table 1

Selected Institutions with Terrestrial and Freshwater Mollusk Collections

Institution	Telephone No.	Number of Specimens thousands
Academy of Natural Sciences of Philadelphia Philadelphia, Pa. 19103	(215) 299-1000	3500
American Museum of Natural History New York, N. Y. 10024	(212) 873-1300	500
Bernice P. Bishop Museum Honolulu, Hawaii 96819	(808) 847-1443	4500
California Academy of Sciences San Francisco, Calif. 94118	(415) 221-5100	100
Carnegie Museum of Natural History Pittsburgh, Pa. 15213	(412) 622-3243	*
Charleston Museum Charleston, S. C. 29401	(803) 722-2996	2
Delaware Museum of Natural History Greenville, Del. 19807	(302) 658-9111	400
Field Museum of Natural History Chicago, Ill. 50505	(312) 922-9410	1600
Florida State Museum Gainesville, Fla. 32611	(904) 392-1721	525
Illinois Natural History Survey Urbana, Ill. 61801	(217) 333-6864 FTS 957-6846	15
Los Angeles County Museum Los Angeles, Calif. 90007	(213) 744-3377	50
Milwaukee Public Museum Milwaukee, Wis. 53233	(414) 278-2700	15

(Continued)

* This collection will soon be transferred to another museum.

Table 1 (Concluded)

Institution	Telephone No.	Number of Specimens thousands
Mississippi Museum of Natural Science Jackson, Miss. 39202	(601) 354-7303	4
Museum of Comparative Zoology, Harvard Boston, Mass.	(617) 495-2468	4500
National Museum of Canada Ottawa, Ontario, Canada	(613) 966-3102	1500
National Museum of Natural History Washington, D. C. 20560	(202) 357-2664	4800
New York State Museum Albany, N. Y. 12230	(518) 474-5800	2
Ohio State University Museum of Zoology Columbus, Ohio 43210	(614) 422-8560 FTS 940-8560	25
San Diego Natural History Museum San Diego, Calif. 92212	(714) 297-3258	25
Santa Barbara Museum Santa Barbara, Calif. 93105	(805) 682-4711	250
State Biological Survey of Kansas Lawrence, Kans.	(913) 844-4493	1
University of Alabama Tuscaloosa, Ala.	(205) 348-7550 FTS 229-1000	15
University of Colorado Museum Boulder, Colo. 80309	(303) 492-6165	250
University of Michigan Museum of Zoology Ann Arbor, Mich. 48109	(313) 764-0470	100
University of Tennessee Knoxville, Tenn.	(615) 974-2144	10

SAMPLING FOR MUSSELS

by

David Nelson*

Introduction

The predominant methods for sampling freshwater mussels including brailing, hand collecting, mechanical dredging, grab sampling, diving, and shoreline sampling, are discussed below. The sampling equipment, how it is used, how to build some of it, and its advantages and disadvantages are also discussed.

Additional information on mussel sampling can be found in Isom (1980), Rasmussen, ed. (1980), Fuller (1978), Brice and Lewis (1979), Jacobson, ed. (1974), Starrett (1971), Parmalee (1967), Coker et al. (1919), and others. Detailed information on the construction, use, and efficiency of various types of equipment is now being prepared at WES.

Brailing

Brailing is conducted with a wood or metal bar equipped with a tow rope and numerous chains with hooks (Figure 1). The bar may be from 2 to 16 ft in length with chains attached every 2 to 3 in. One to eight hooks are attached to the chains. The bar is towed with a power boat so that the hooks drag the river bottom in a downstream direction. (Commercial clammers sometimes use a mule, which is a form of underwater sail that makes use of the river current to power and guide the boat (Coker 1919 and Emanual in Rasmussen, ed. 1980).) The open mussels clamp down on the tines of the hooks and are extracted from the substrate.

The brail runs, or tows, are made in transects either by timing the duration of the run or by using landmarks to mark the beginning and end of the runs. Landmarks are more desirable because they can be used later to mark transects on areal photos or navigation charts. This provides a permanent record of the exact transect locations and eliminates the need for a similar survey of the same area.

Once a brail run is completed, the bar is lifted and the mussels are removed from the tines. When possible, instead of tossing the mussels back into the water, they should be relocated in a low-to-moderate flow current since high flows may cause a higher mortality.

A brail bar can be built from any standard 2 by 4 (1-1/2 by

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3-1/2 in.) board, but oak, ash, cypress, or other hardwoods are the most sturdy and will withstand harsh use. Boards with knots should be avoided, as the knots will weaken the board and may be a point-of-breakage A 10-ft-long bar with 40 chains and 200 hooks (5 per chain) has been recommended by Bumgarner (1980) as a "standard" bar for studies on the Upper Mississippi River. The 10-ft size is close to the maximum size that can be handled without a winch. The length of the bar may be varied to accommodate the size of the sampling boat, the size of the river being sampled, the extent of the sampling effort, and the ability of the mussel surveyor.

Screw eyes are screwed into the brail bar at 3-in. intervals (Figure 2). Fence braids (horseshoe-shaped nails) or eye bolts can also be used. The balance center of the bar must be found, and measurements must be made toward the ends of the bar. From that point (Emanuel personal communication) "S"-hooks are attached to the screw eyes and then to 12-in. chains. Snap hooks are then added so that the chains can easily be removed for storage and transportation and for testing various hooks. Three eye bolts are bolted to the bar, one at the balance center, and two, 41-1/2 in. from the center eye bolt, toward the two ends of the board. A bridle rope is attached to the three eye bolts on the bar and to a metal round ring on the other end. If all the materials are accessible (including the assembled hooks), a bar can be assembled by a novice in 8 to 10 man-hours.

Since hooks of the type required for biological sampling may not be readily available, it might be necessary to manufacture one's own (Figures 3-7). These hooks are simple to fashion, but time-consuming, averaging 6 to 10 min per hook. The hooks are made of a stiff, spring wire (like music wire), as small as possible, but yet large enough to maintain their shape when dragged along the river bottom. Soft wire will bend and would require frequent reshaping to be effective during brailing. Some researchers recommend using various size wires to catch various sizes of mussels (Fuller personal communication and Thiel personal communication). A small stiff wire would collect large mussels as well as small ones if the closure on the tines by the mussels is tight enough. Hook-making requires very basic equipment: pliers, vise-grips, bolt cutters, vise, and gloves.

Once completed, the hooks are attached to the 1-ft-long chains with "S" hooks (Figure 8). These hooks are placed at various points on the chain and the higher hooks will drag when the bar is pulled too close to the bottom.

Occasionally the hooks are beaded by melting the tips of the tines with a cutting torch or by soldering a bead on the tine. Varying opinions exist on the purpose of the bead. The bead may help to hold the mussel on the hook, but is may also damage the mussel if it is not removed from the hook carefully. Sparks (personal communication) of the Illinois Natural History Survey found when surveying the Spoon River in Illinois that the mussels clamped down on the tines tightly enough so

that a bead was not necessary. Another opinion is that the bead is used by commercial clammers to restrict the collection of smaller non-commercially valuable mussels (Coker 1919). Peach (personal communication) of the American Shell Company feels that the bead allows the hook to securely hold larger mussels that are extracted from the substrate.

The two most prevalent types of commercial hooks are the crowfoot and dovetail (Coker 1919 and Emanuel in Rasmussen 1980). The crowfoot hook (Figure 9) digs into the substrate and extracts deeply implanted mussels, but it also hooks onto other bottom obstacles and penetrates farther into mussel soft parts, sometimes causing damage. The dovetail hook (Figure 10) has become the most commonly used commercial hook because it tends to slide over obstructions.

Another adaption to experimental hooks is to tie stiff monofilament line to the tines of the hooks for collecting small mussels. Sparks (personal communication) tried this on the Spoon River and found it effective for sampling young mussels.

The brail method has an advantage in that the brail can be used to survey large areas in a relatively short time and it can be used in deep waters. The equipment is also inexpensive, and simple to use.

This method has disadvantages, too. Although the method can be used somewhat qualitatively to help determine the species present, it cannot be used quantitatively. The brail had an 0.77 average catch efficiency in a study by Thiel, Talbot, and Holzer (1980). This method may be selective for certain sizes and species. The sampling success is temperature- and seasonally-variable. If the experimental hooks cannot be purchased, the hooks will have to be built and this is labor intensive. The brail tangles easily, making it difficult to use in rivers with numerous snags. Brailing may (a) break thin-shelled species when the hooks are dragged across them, (b) cause mussels to be relocated to unsuitable substrates when they are extracted from the river bottom, (c) damage the shell when carelessly removed from the hooks, and (d) cause gravid mussels to abort the immature spawn when disturbed by the brailing.

Hand Collecting

Hand collecting in shallow water is another method for gathering mussels, and it is sometimes referred to as pollywogging (Fuller 1978). A clear-bottom bucket may be useful for observing the substrate when hand collecting. This bucket is made by cutting the bottom out of a plastic or metal bucket, leaving a 1 to 2 in. ledge, and by replacing it with clear plastic or glass. Both sides of the new bottom are then sealed into place with silicone adhesive (Figure 11).

Another useful tool is the mussel rake, which is a garden rake with netting or hardware cloth sewn to it (Figures 12-13). The rake is pulled along the river bottom and the mussels are trapped in the net.

Hand collecting has the advantage of being qualitative and quantitative when done by transects or quadrates. It requires no special equipment and is not size- or species-selective. The disadvantages of hand collecting are that it is restricted to shallow water and is labor intensive.

Mechanical Dredging

Mechanical dredging involves the use of a dredge consisting of a rectangular-shaped box with metal mesh sides and the front end open. The front end has rounded rakelike teeth that dig into the substrate as the entire apparatus is being pulled by a boat. The dredge is then winched up and its contents dumped into the boat.

One of the advantages of dredging is that the dredge can be designed to select all sizes and species of mussel and may be somewhat quantitative.

Disadvantages of dredging are (a) estimating the size of the sample area is often difficult, (b) the dredge is very heavy and a large boat and winch are required to operate it, and (c) the dredge tears up the substrate and can break and crush the shells.

Grab Sampling

Grab sampling is a method by which a metal device with jaws is attached to a rope and dropped to the river bottom where it grabs a portion of the substrate. A number of different grabs are available but the most common are Ekman, Standard Ponar, Petite Ponar, Peterson, and Shipek. The Ekman grab, which is lightweight, is used for slow current and soft bottoms. The Standard Ponar (45 lb) and Petite Ponar (15 lb) grabs, which are heavier, can be used in moderate current to sample soft to moderately consolidated substrate. The Peterson grab weighs at least 75 lb and can be used in fast current and in most substrates. The Shipek grab (134 lb) can be used in fast current and can sample consolidated substrates.

Grab samplers are easy to operate, quantitative, and qualitative. The heavier grabs can be used in high velocity current. The grabs not only sample the mussels but also provide a substrate sample.

However, grab samplers collect a small sample at a specific depth, thus requiring a large number of samples for a given area. This is time

consuming and labor intensive. The larger grabs require a winch and large boat to operate.

Diving

Diving involves the use of SCUBA, snorkel, or hookah (bandmask and hose) to hand pick mussels off the bottom. A hose is connected to the bandmask and to a compressor or air tanks on the surface. The bandmask is also equipped with a depth gauge and communication system which are linked with the surface. A person at the surface can then write down data as they are transmitted from the diver.

A quadrate can be used in gathering quantitative information. This is a square shaped frame which is used to outline a standard size area. Various sizes of quadrates are used--1/2 m^2, m^2, and 25 ft^2 (Sickel 1980 and Thiel, Talbot, and Holzer 1980). Some researchers recommend using the larger 25-ft^2 quadrate (Figure 14) (Thiel personal communication) for sampling while others suggest using smaller quadrates and taking more samples. The m^2 quadrate is a good working size for an adequate sample, for transportation, and for statistical analysis, but the size and number of samples should be adapted to each study during the sampling design phase. An example of a quadrate built from 3/4-in. PVC is in Figure 15. In high velocity currents, weights may need to be attached to this device to anchor it (Figure 16).

The advantages of diving are that different sizes, species, and numerical abundance of mussels can be collected and there is a minimum of disturbance to nontarget mussels. Also, once identified, the mussels can be replaced into the substrate by hand.

The disadvantages of diving are: (a) if smaller sized mussels are not specifically sought after they may be missed while diving, (b) diving is expensive, time consuming, and dangerous in high velocity currents, and (c) in turbid water, mussel sampling has to be done by feel.

Shoreline Sampling

Shoreline sampling is simply walking along the shore looking for dead mussels which have either washed up or have been carried ashore by raccoons or muskrats. This method is not qualitative or quantitative, but may be indicative of species assemblages. Shoreline sampling requires only a minimum amount of time and can provide supplemental information.

Summary

Probably the most valuable "survey tools" are one's eyes and ears. Read the available literature and contact knowledgeable people, including local experts, malacologists, state and Federal biologists, shell clubs, and commercial clammers for information on the presence of freshwater mussels in your study area.

A standardized data sheet is valuable for recording and organizing data.

The use of mechanical dredges should be avoided because of fauna and substrate damage.

Standard equipment should be used when possible, but equipment and methods will have to be determined using a combination of the described sampling methods for each situation.

For cursory surveys in large rivers, brailing is the most rapid and cost-effective means of surveying.

A substrate sample taken with a Petite Ponar for each transect may be indicative of the species assemblages since occurrence of certain species is related to sediment composition (Coker, et al. 1921, Harman 1972, and Sickel 1980).

In shallow water, hand-picking (pollywogging) is probably the most accurate and efficient method.

Diving is probably the most accurate method for deepwater sampling, but may be restricted by high costs and potential safety risks.

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Discussion

A. Clarke: Why have commercial brailers stopped using wheels on their brail bars?

J. Peach: Wheels can jam in rocks, brush, and other debris.

B. Buselmier: Describe the reasons for using beaded hooks.

D. Nelson: The bead on the tip of the hook helps to keep the mollusk from slipping off the wire.

J. Bushman: Can the beading damage the shell?

D. Nelson: Yes. When the mollusk is removed from the hook the beads often chip the shell edges.

J. Kessler: Concerning beads made from liquid steel, this material is an epoxy which can be quite abrasive to shells.

Comment: In constructing brail hooks you should consider using a fence splicer to save time.

J. Peach: I would like to comment on the size of the brail bars. If a 10-ft bar with 40 chains, 5 hooks per chain, is used, a large boat will be necessary.

J. Kessler: I fail to understand the reason for specifying a particular length of bar. This technique is by no means quantitative.

D. Nelson: This is the size of bar we have found to be convenient. We are telling you what we did, not what to do.

A. Miller: WES is not going to suggest that a District only use a specific length of bar. This is a recommended length that many have found to work well.

A Clarke: A brail is not even a qualitative technique. "Qualitative" implies that at least some of each species will be taken. A brail may not collect any of certain types or sizes of mollusks.

J. Bushman: I believe it is important to state exactly which type of bar was used for a particular habitat and the success of that particular type of equipment.

P. Yokely: Also realize that you can loose a brail in a river. When you go collecting, take several brails.

J. Williams: Do you have any figures on the species and sizes of mollusks collected with particular types of hooks?

D. Nelson: We hope to accomplish this type of work as part of this project.

P. Yokely: Have you found that time of year, water temperature, and season have an effect on sampling with a brail?

D. Nelson: Yes. Water temperature has an effect. If it is cold, the mussels will not be taken with brail hooks.

NOTE: The above questions and answers were rewritten from notes taken by a stenographer.

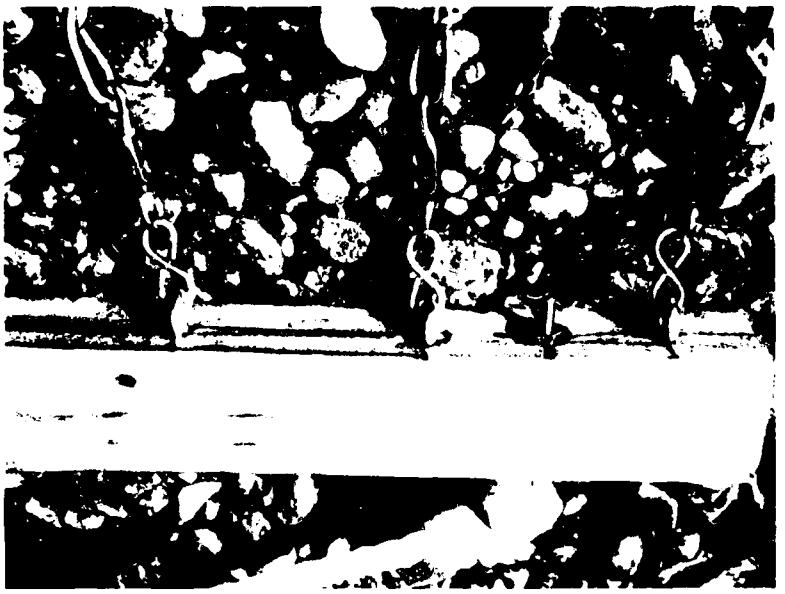

Figure 1. Brailing

Figure 2. Screw eyes on brail bar

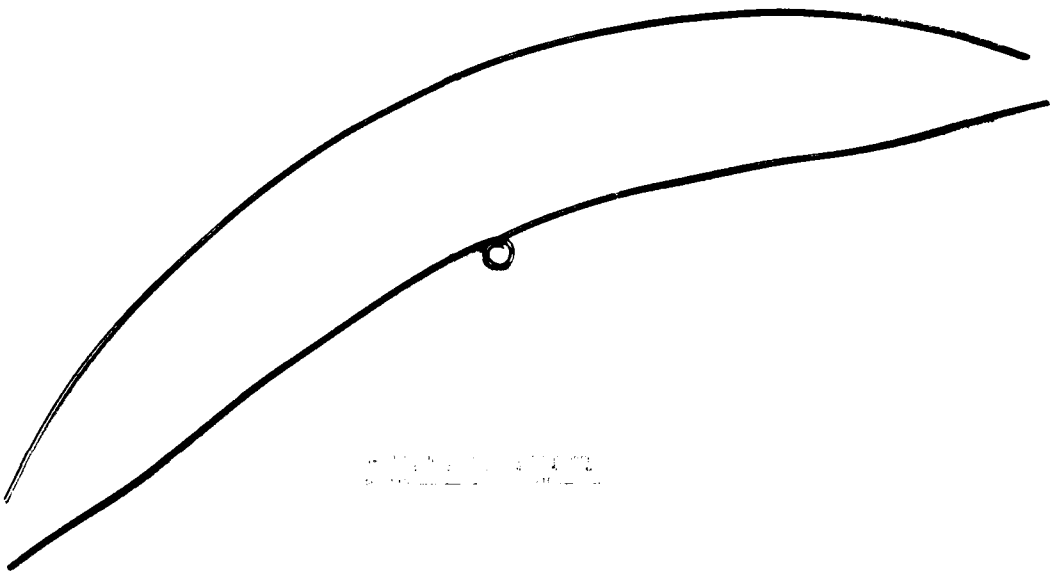

Figure 3. Steps in constructing brail hooks. A loop is placed in the center of a straight wire

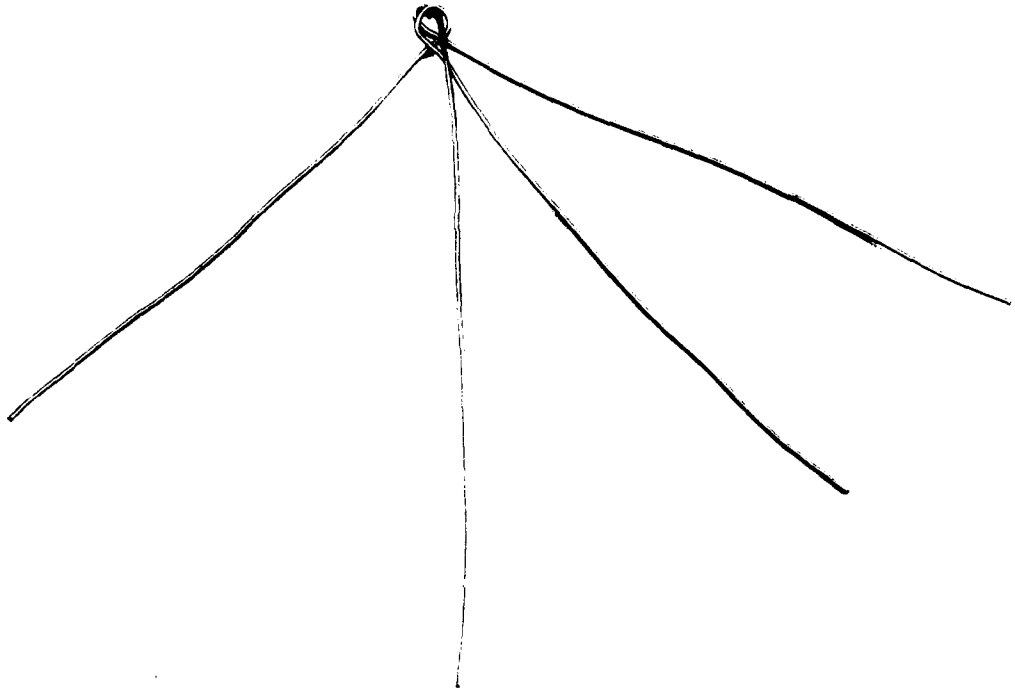

Figure 4. A second wire is threaded through the first loop

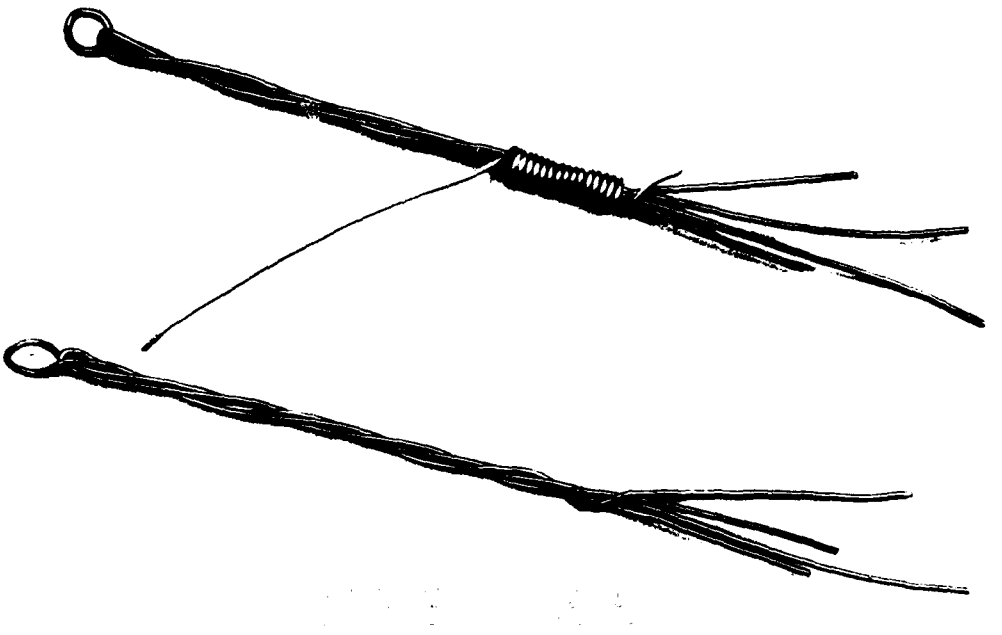

Figure 5. The two sets of wire are brought together and twisted. Using soft wire the four strands are made secure

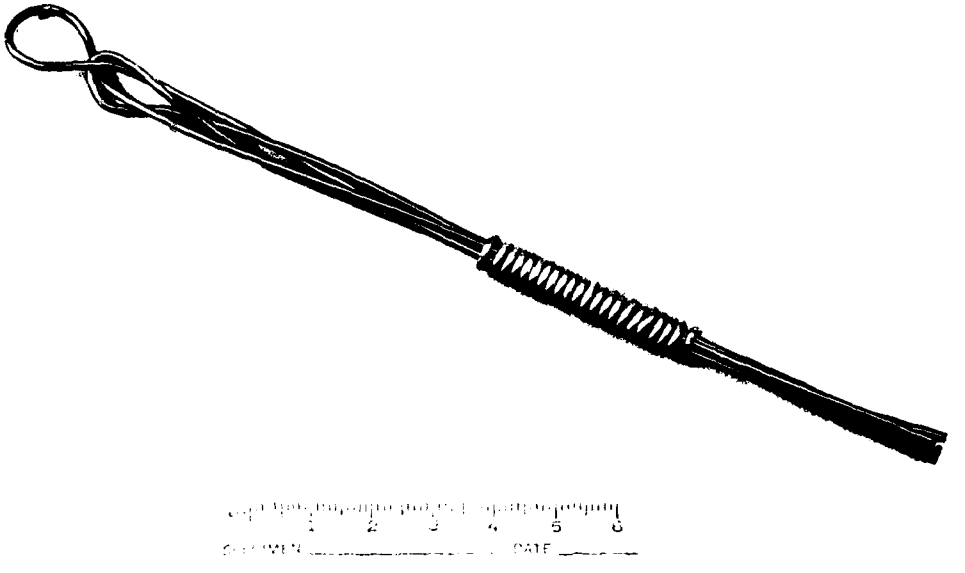

Figure 6. The soft wire is pulled tight

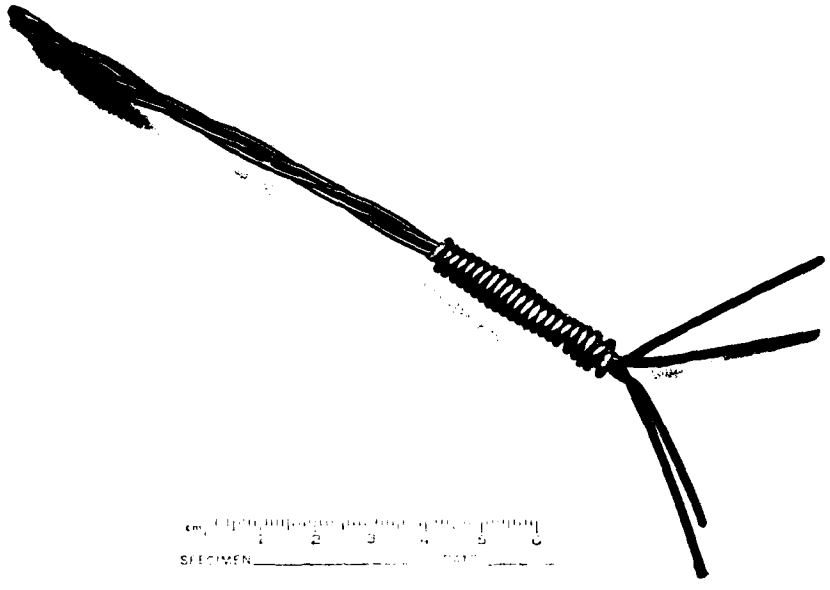

Figure 7. The ends of the hook are spread. Beads should be attached to the ends

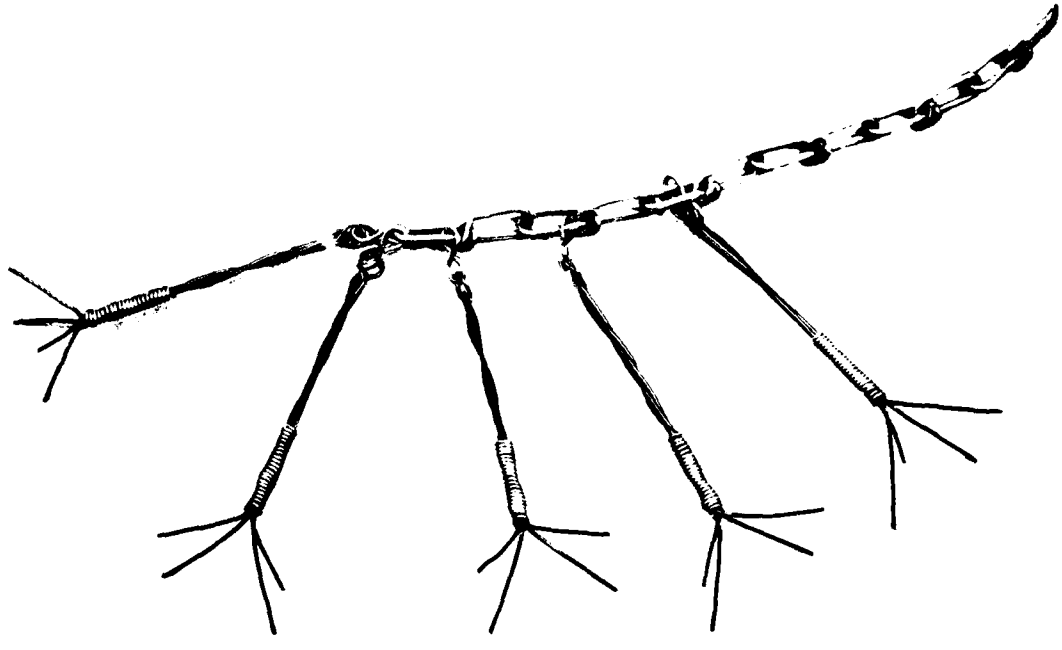

Figure 8. Hooks attached to chains with "S" hooks

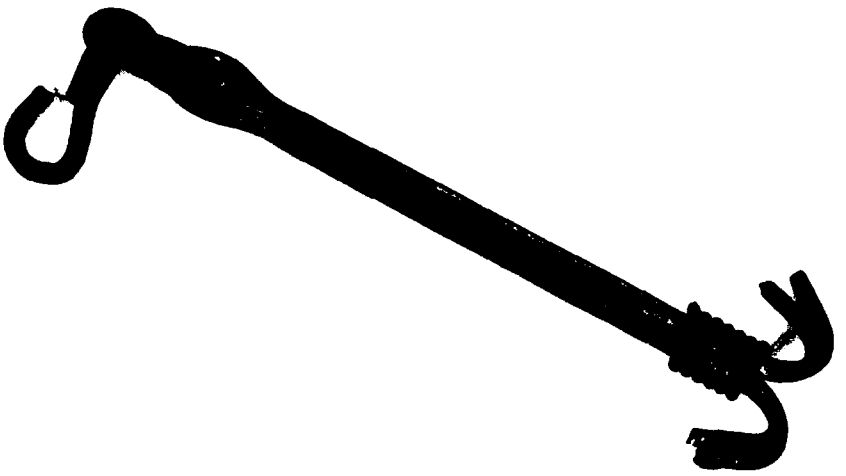

Figure 9. Crowfoot hook

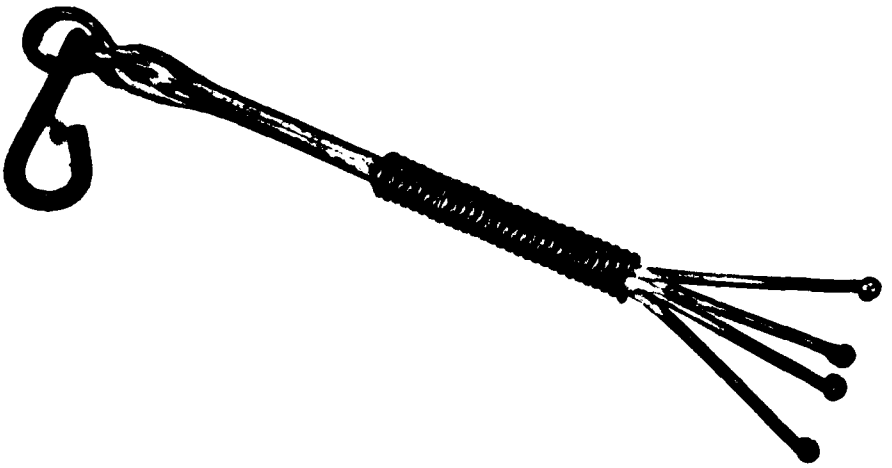

Figure 10. Dovetail hook

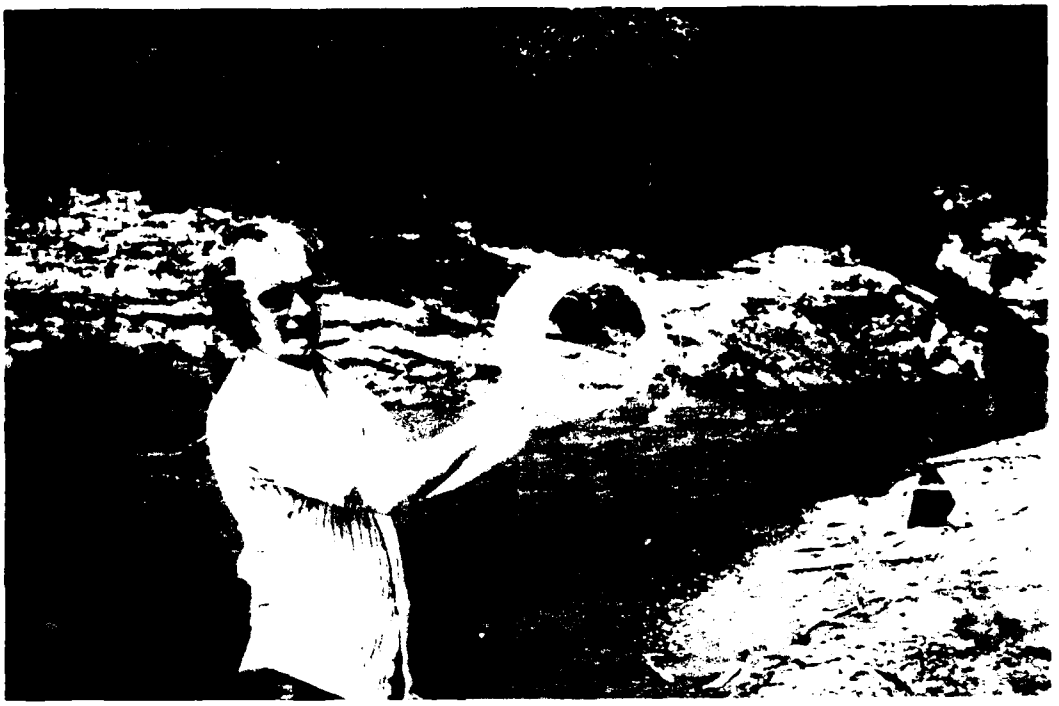

Figure 11. A see-through bucket made by sealing a plexiglass bottom in a 5-gal bucket using silicone adhesive

Figure 12. Mussel rake

Figure 13. Closer view of mussel rake

Figure 14. A 25-ft^2 quadrate

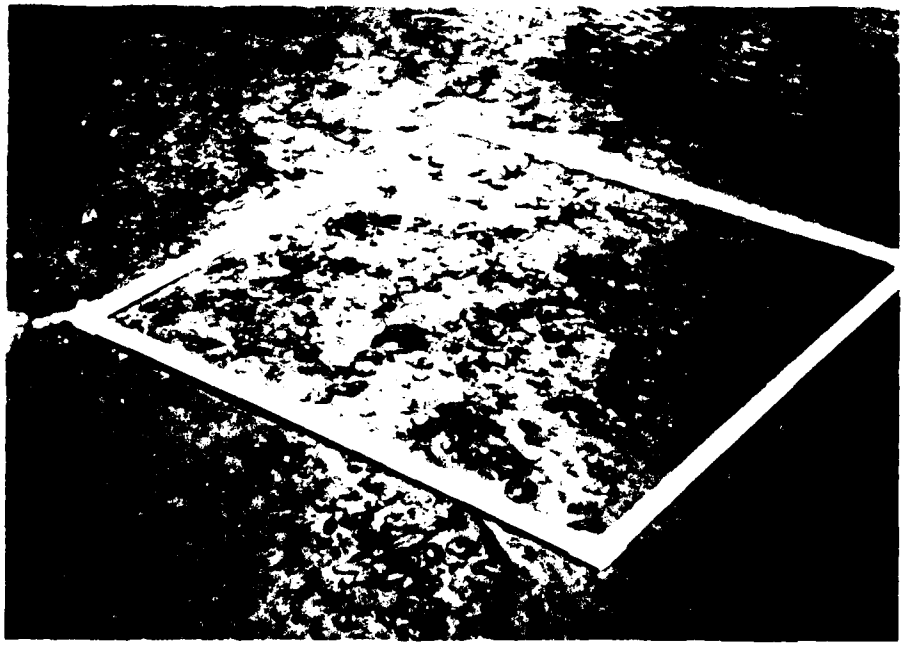

Figure 15. Quadrate built from 3/4-in. PVC

Figure 16. Weights attached to anchor a 1-in.^{2} quadrate

DISTRIBUTION AND HABITAT OBSERVATIONS OF SELECTED MOBILE BASIN UNIONID MOLLUSKS

by

James David Williams*

Introduction

The watershed of the Mobile Basin (Figure 1), the largest Gulf Coast river basin east of the Mississippi River, comprises an area of approximately 44,000 square miles in Alabama, northwest Georgia, and northeast Mississippi. It drains portions of several physiographic provinces, producing a variety of aquatic habitats. Its large size, diverse habitats, geographic barriers (i.e., Fall Line), and proximity to diverse aquatic faunas in adjacent drainages all combine to produce an extremely rich aquatic fauna. The diverse Mobile Basin mollusk and fish fauna is especially noteworthy for its high degree of endemism.

This paper reviews the geographical distribution of five unionid mussel species (*Quadrula stapes*, Lea 1831, *Pleurobema curtum*, Lea 1859, *Pleurobema marshalli*, Frierson 1927, *Pleurobema taitianum*, Lea 1834, and *Epioblasma penita*, Conrad 1834) endemic to the Mobile Basin. These species were selected because the alteration of riverine habitat in the Mobile Basin during the past 20 years has drastically restricted their range and greatly reduced their numbers. In the past, these species have been reported from the main channel of Coastal Plain rivers of the Mobile Basin in Alabama and Mississippi. General observations on the habitat of these species in the upper Tombigbee River system in Alabama and Mississippi are also presented.

The Tombigbee River is the westernmost drainage in the Mobile Basin (Figure 2). From its headwaters in Prentiss and Tishomingo Counties in northeast Mississippi, it flows in a south to southeasterly direction where it joins the Black Warrior River in Green Country near Demopolis, Alabama. From Demopolis, it flows south through western Alabama, joining the Alabama River to form the Mobile River at the southern tip of Clarke County. Upstream of its junction with the Black Warrior River at Demopolis, it is generally referred to as the upper Tombigbee; below Demopolis, it is referred to as the lower Tombigbee.

The first unionid mollusks collected from the rivers of the Mobile Basin were taken during the early 1800's. Many of these specimens were utilized in the description of new species by Issac Lea and Timothy A. Conrad. In 1876, James Lewis published a report on the mollusk fauna of its tributaries. Anson A. Hinkley (1906) published a report on some

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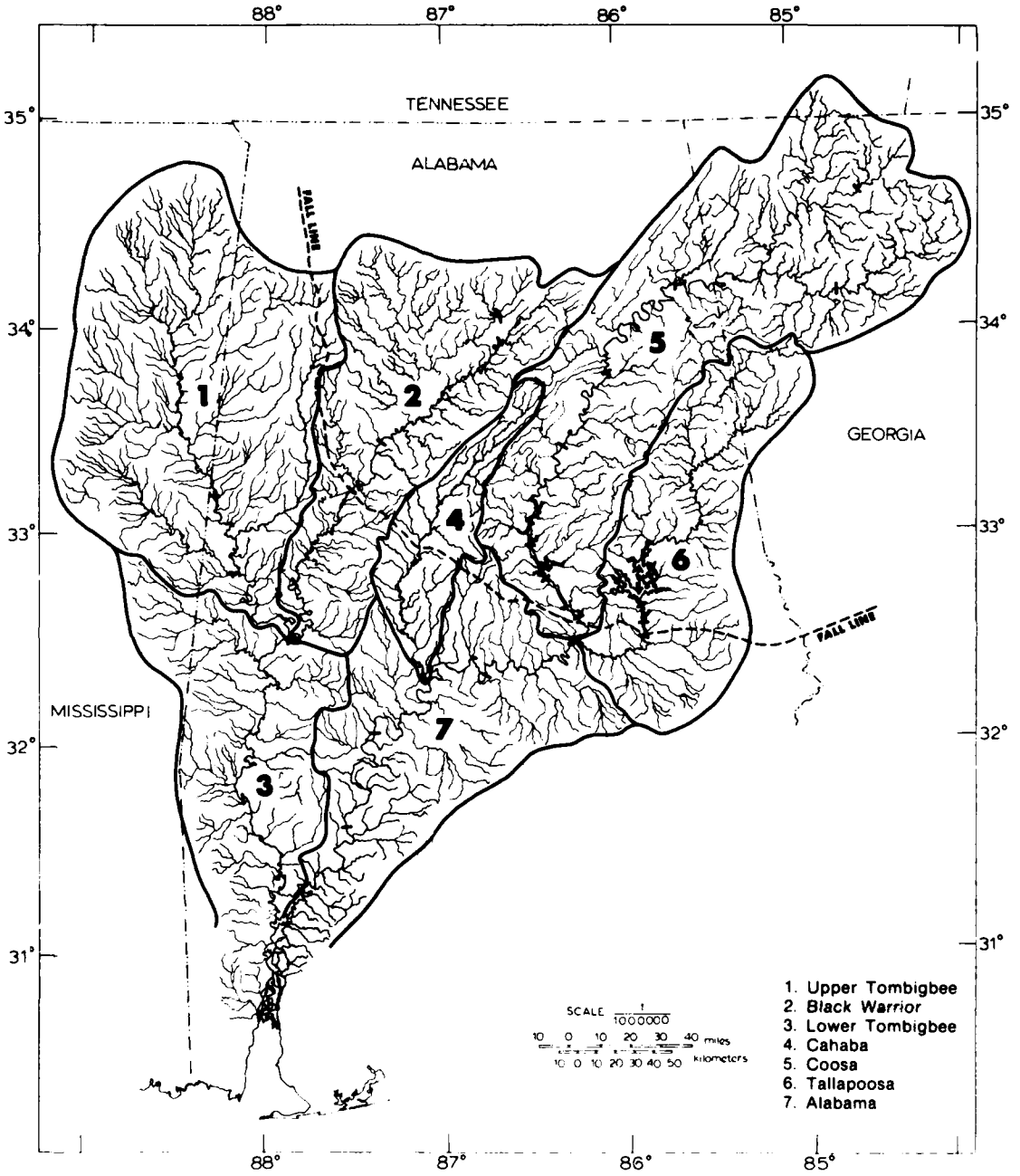

Figure 1. The major river systems of the Mobile Basin in Alabama, Georgia, Mississippi, and Tennessee

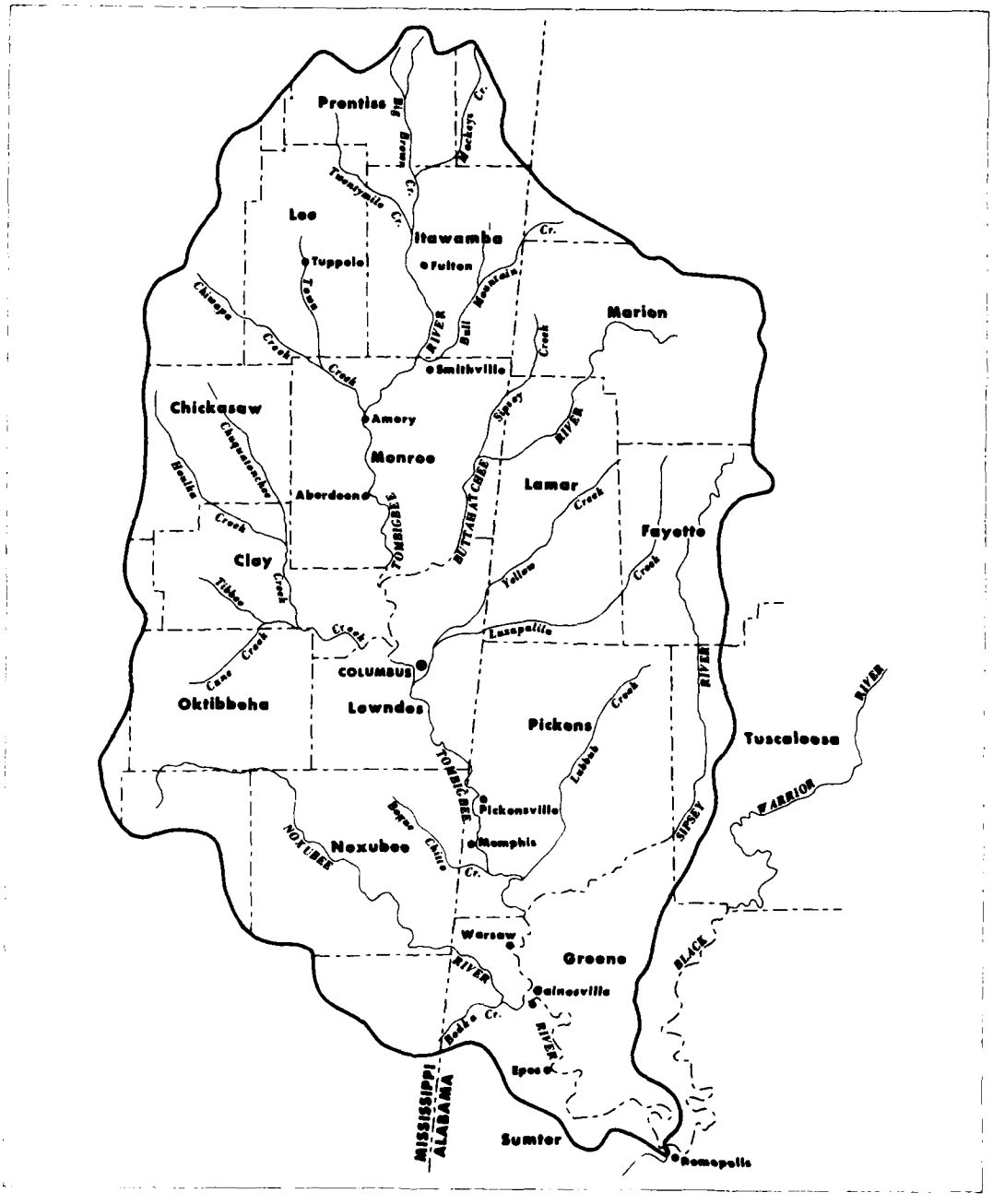

Figure 2. The Upper Tombigbee River system in Alabama and Mississippi. Only communities along the river and major tributaries are included

shells from Mississippi and Alabama which included 40 species from the Tombigbee River system. In 1939, van der Schalie reported on the unionid mollusks of the Tombigbee River and described a new species, ***Medionidus mcglameriae***, from the Tombigbee River at Epes, Alabama.

Methods

Recent (1972-1978) distribution and habitat data for the five unionid mussels reported from the upper Tombigbee River are based primarily on material collected by James D. Williams accompanied by David H. Stansbery, Randall Grace, Vicki Pearson, Glen Clemmer, Herbert Boschung, Phil Mundy, and Thomas Jandebeur. Most specimens were collected by hand from middens of mammals associated with the riverine habitat and from shoals adjacent to the middens. Additional material was taken by hand from shallows around sand and gravel islands and bars. Several deep-water (5-8 m) collections were made by Randall Grace using SCUBA gear. Specimens collected have been deposited in the Ohio State University Museum of Zoology in Columbus, Ohio. Literature records of species from the Tombigbee River and other Mobile Basin streams were used in determining general distribution. Additional distributional data were obtained from material deposited in the Smithsonian Institution (United States National Museum, USNM), Washington, D. C., and the Mississippi Museum of Natural Science (MMNS), Jackson, Mississippi.

There are no standardized common names for the naiades discussed herein. The common names used herein were taken from those used in earlier reports and others are new recommendations.

Description of the Upper Tombigbee

The upper Tombigbee River watershed, with a drainage area of approximately 10,000 square miles, is almost entirely developed on Coastal Plain sediments. It drains portions of five physiographic divisions with two divisions, the Fall Line Hills and Black Belt, comprising approximately 80 percent of the drainage basin. The main channel of the upper Tombigbee generally follows the boundary between Fall Line Hills and the Black Belt. Elevations along the river proper range from 200 ft near Amory, Mississippi, to approximately 50 ft at the Demopolis Lock and Dam. Until recently (1973-1981) the upper Tombigbee River above Gainesville, Alabama, was the largest unimpounded river in the Mobile Basin. Construction of the Tennessee-Tombigbee Waterway has drastically altered the riverine habitat and its associated aquatic fauna. Information on the unionid mollusks of the upper Tombigbee included in this paper was obtained prior to and during the early stages of construction.

Prior to construction of the Tennessee-Tombigbee Waterway, the only impounded waters in the main channel of the upper Tombigbee River

were from Demopolis Dam. This structure was completed in 1954 and impounded 68 miles of the upper Tombigbee River between Demopolis and Gainesville, Alabama. Before impoundment, this section of the river was probably not unlike the river between Gainesville and Pickensville, Alabama. Old (pre-1960) U. S. Geological Survey maps of the area above Demopolis show islands, bars, and shoals interspersed among long stretches of deeper quiet water. The naiades reported by van der Schalie (1939a) from the Tombigbee River at Epes, Alabama, were taken from shoals and bars.

The Upper Tombigbee River from the vicinity of Gainesville upstream to the area a few miles above Pickensville was characterized by alternating shoals and deeper still water. The river channel ranged in width from approximately 50 to 110 m. Substrate in the shoal areas was gravel or a mixture of gravel, sand, and clay. Current under normal flow conditions varied from approximately 2 m/sec in areas where the channel was constricted (50 m wide) to less than 0.3 m/sec in areas where the channel was deep and wide. In the shoal areas where the channel was 75 to 100 m wide, the velocity was approximately 1 m/sec. A gravel shoal area near Gainesville (Figure 3) was typical of this section of the river. Several naiad collections taken in this reach of the river yielded more than 300 individuals representing more than 30 species.

Moving upstream from the Alabama-Mississippi State line, northwest of Pickensville, the character of the upper Tombigbee gradually changed. The channel was noticeably smaller, 40 to 80 m in width, with a gradual increase in sand and gravel shoal areas. The area around Buzzards Island, south of Columbus, Mississippi (Figure 4), was typical of this reach. The impact from human activities, agriculture, industrial development, and gravel dredging was more evident in this reach than the section below Pickensville. While there was a slight decrease in naiad diversity, there was a considerable decrease in abundance. This was probably due to a combination of decreased stream size and increased human impacts.

The upstream section of the upper Tombigbee River, which includes a portion of the East Fork of the Tombigbee, extends from the mouth of the Buttahatchie River (Figure 5) upstream to the vicinity of Smithville, Mississippi (Figure 6). The Buttahatchie River at its junction with the Tombigbee is almost as large as the Tombigbee and it could be considered an extension of that river. The numerous gravel shoals in the lower Buttahatchie are very similar to shoal areas farther downstream in the Tombigbee River. The river channel in this section ranged from 20 to 40 m in width. Above the junction of the Buttahatchie River, the Tombigbee showed a noticeable increase in the amount of sand and silt associated with the gravel shoals. This may be due in part to poor agricultural practices during the early 1900's. Van der Schalie (1939a) reported finding silt "knee-deep" in the Tombigbee River at Aberdeen in 1931. The increased silt load may also have resulted from gravel dredging in the vicinity of Amory, Mississippi. These factors may have

Figure 3. Tombigbee River (looking downstream) prior to impoundment, approximately 0.5 miles upstream from the Gainesville Dam, Sumter-Green Co. line, Alabama. The photograph was taken 26 October 1973

Figure 4. Tombigbee River (looking downstream) from the downstream end of Buzzards Islands, approximately 5 miles south of Columbus, Lowndes Co., Mississippi. The photograph was taken September 1971

Figure 5. Tombigbee River (looking upstream) from its junction with the Buttahatchie River, Monroe Co., Mississippi. The mouth of the Buttahatchie River is in the lower right corner of the photograph. The photograph was taken 25 July 1972

Figure 6. Tombigbee River (looking upstream) 2.7 miles west of Smithville, Monroe Co., Mississippi. The photograph was taken 28 July 1974

caused the striking reduction in naiad diversity and abundance for a distance of approximately 15 miles upstream and downstream of Aberdeen.

At present, the Tennessee-Tombigbee Waterway is more than 40 percent complete. The Gainesville, Aliceville, and Columbus locks and dams are complete and have been closed. The Aberdeen Lock and Dam, when completed, will impound the upper Tombigbee to the vicinity of Amory, Mississippi. This series of four impoundments will dramatically alter the riverine ecosystem of the upper Tombigbee River. The river bendways at cutoffs immediately below the dams resemble, to some extent, the pre-impoundment riverine ecosystem.

While the East Fork of the Tombigbee River will not be impounded, the canal section of the Tennessee-Tombigbee Waterway will parallel it for a distance of approximately 35 miles. The extent of the impacts resulting from increased siltation during construction and alteration of flow and water quality have not been determined. Considering the relatively large size of the construction zone (up to 1 mile wide) along the canal section and the relatively small size and flow of the East Fork, the impacts could be considerable.

Accounts of Selected Species

The unionid mollusk fauna of the main channel of the Upper Tombigbee River was very diverse, consisting of more than 40 species. Approximately 75 percent are wide-ranging species which occur in several river systems outside of the Mobile Basin and adjacent Gulf Coast drainages. The remaining 25 percent are species restricted to the Mobile Basin and one or two other Gulf Coast rivers.

The limited distribution and restricted habitat of the Mobile Basin-Gulf Coast endemics make them extremely vulnerable to extirpation by the slightest alteration of their habitat. Impoundment and dredging of the main channel of the Coosa, Alabama, upper and lower Tombigbee, and Black Warrior Rivers has eliminated or drastically altered most of the available habitat of several endemic unionid mollusks. Based on current distributional data, the five species discussed below are endemic to the large rivers of the Mobile Basin.

Quadrula stapes (Lea 1831)
stirrup naiad, Figure 7

Original description--*Unio stapes*, Plate 7, Figure 8. Lea, I. 1831. "Observations on the Naiades, and Descriptions of New Species of That, and Other Families," Trans. Amer. Philos. Soc. (N.S.), Vol 4, pp 63-121, Plates 3-18.

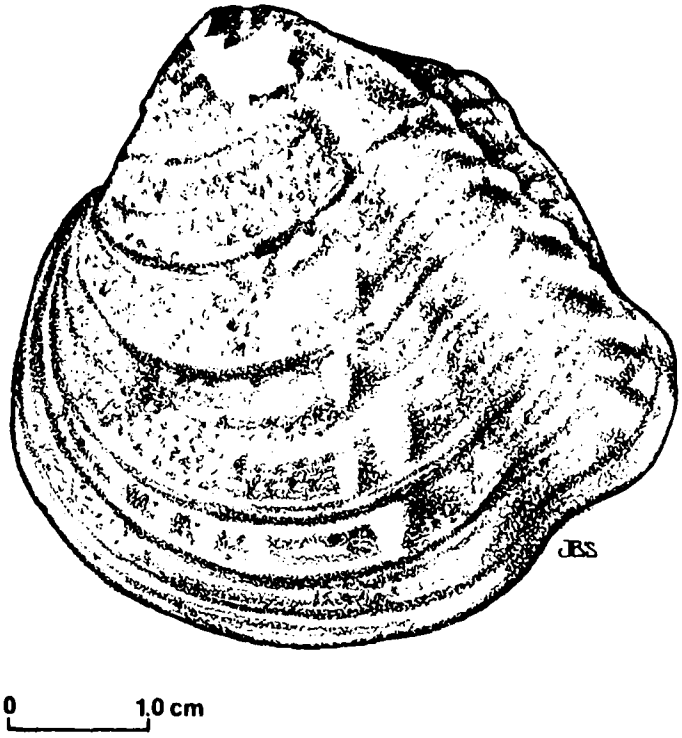

Figure 7. *Quadrula stapes* (Lea 1831). USNM 809731. Tombigbee River at Memphis Landing, River Mile 324.4, Pickens Co., Alabama, 24 October 1976

The stirrup naiad is one of the most distinctive species in the Mobile Basin. In young specimens, the periostracum is yellow to yellowish-green with greenish zigzag markings, while older individuals are typically dark yellowish-brown to brown in color. *Quadrula stapes* appears to be most closely related to *Q. intermedia* which is endemic to the Tennessee River system.

The stirrup naiad is known only from the Tombigbee, Black Warrior, and Alabama Rivers of the Mobile Basin. There is one report (Lewis 1876) of this species from the Tennessee River but this appears to be erroneous. Specimens on which Lea (1831) based his original description were received from Judge Tait of Claiborne, Alabama, on the Alabama River. Conrad (1834a) reported it from the Black Warrior River but did not give a specific locality. One specimen of *Quadrula stapes* was recently recovered from an Indian midden on the south bank of the Black Warrior River, southwest of Tuscaloosa, Alabama (Hanley 1982). Simpson (1900) subsequently reported it from the Alabama and Tombigbee Rivers. The apparent absence of *Q. stapes* from the Coosa and Cahaba Rivers appears real in view of the amount of collecting in these streams during the 1800's and early 1900's. A recent survey of the unionacean mollusks of the Coosa River drainage (Hurd 1974) did not reveal this species.

Hinkley (1906) reported *Q. stapes* from the Tombigbee River at Columbus, Mississippi, and van der Schalie (1939a) reported it from the Tombigbee River at Epes, Alabama. Recent collections (in the 1970's) by Williams et al. in the main channel of the upper Tombigbee River prior to impoundment revealed this species at 17 sites between 2 miles north of Gainesville, Alabama, upstream to 0.5 miles below the Mississippi Route 50 bridge, approximately 6.4 miles northwest of Columbus, Mississippi. Samples taken from several larger streams tributary to the upper Tombigbee River have yielded one specimen of *Q. stapes*, which was collected in the lower portion of the Sipsey River below Lewiston, Greene County, Alabama (Paul Yokley personal communication). This is the only record of this species in a Tombigbee River tributary.

In the upper Tombigbee River, the habitat of the stirrup naiad was shoal areas with moderate to swift current over clean coarse gravel substrate. Living specimens were taken in water up to approximately 0.7 m deep. Fresh specimens with some mussel tissue still attached to the shell were taken from middens on large logs in shoal areas in water up to 1.3 m deep. Substrate and current around these logs were similar to that described above for living specimens.

Pleurobema curtum (Lea 1859)
black club naiad, Figure 8

Original description--*Unio curtus*. Lea, I. 1859. "Descriptions of Eight New Species of Unionidae, from Georgia, Mississippi, and Texas," Proc. Acad. Nat. Sci. Phila., Vol 11, pp 112-113.

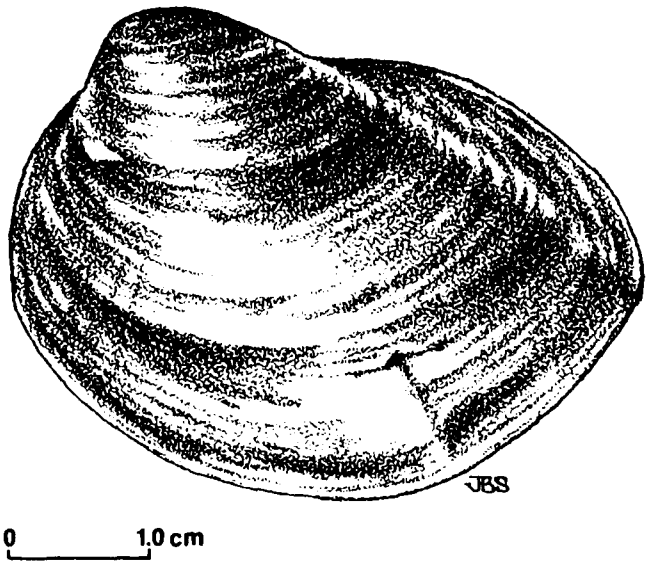

Figure 8. *Pleurobema curtum* (Lea 1859). USNM 809732. Tombigbee River at Memphis Landing, River Mile 324.4, Pickens Co., Alabama, 24 October 1976

The black club naiad (*Pleurobema curtum*) is but one of perhaps 10 species of this genus restricted to the rivers of the Mobile Basin. The type series of *P. curtum* was collected by William Spillman, M.D., from the Tombigbee River, at Columbus, Mississippi. No specimens have been collected outside the upper Tombigbee River system. Hinkley (1906) did report *P. curtum* from the Big Black River, a tributary of the Mississippi River, in west-central Mississippi. The specimens on which this record is based have not been located. It is likely that Hinkley made an error in identification and confused *P. curtum* with *Obovaria jacksoniana* (Frierson 1912) which is superficially similar to *P. curtum*. Also, recent collections from the Big Black River by biologists from the Mississippi Museum of Natural History have not yielded any *P. curtum*. Burch (1975) gives the distribution as "Tombigbee River, Mississippi."

In the upper Tombigbee River system, *P. curtum* is known from three localities in Alabama from 0.5 mile east of Memphis, Pickens Co., upstream to 300 yd above the Pickensville boat landing, Pickens Co., and two localities in Mississippi near Smithville, Monroe, and Itawamba Counties. Habitat for the black club naiad in the main channel of the upper Tombigbee River was a gravel bottom mixed with sand, with moderate to swift current. Shoals in the Memphis and Pickensville area where live specimens were collected ranged in depth from 0.3 to 1.3 m. Live specimens were taken by hand at a depth of approximately 0.5 m. In the East Fork near Smithville, the substrate was predominantly gravel but there was more sand in this area than in the vicinity of Pickensville.

Pleurobema marshalli (Frierson 1927)
Marshall's naiad, Figure 9

Original description--*Pleurobema marshalli*. Frierson, L. 1927. "A Classified and Annotated Check List of the North American Naiades," Baylor University Press, Waco, Tex., 111 pp.

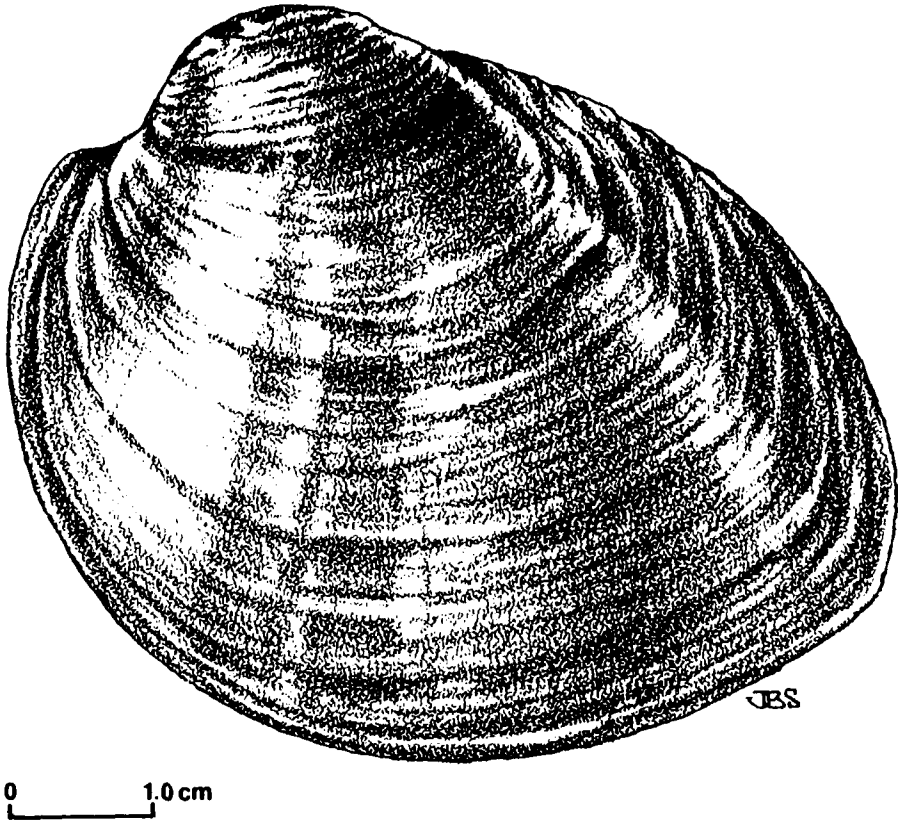

Figure 9. *Pleurobema marshalli* (Frierson 1927). USNM 809733. Tombigbee River at Memphis Landing, River Mile 324.4, Pickens Co., Alabama, 24 October 1976

Marshall's naiad (*Pleurobema marshalli*) is distinctive and not easily confused with other members of the genus *Pleurobema* in the Mobile Basin. Types of this species were collected by A. A. Hinkley from the Tombigbee River at Boligee, Greene County, Alabama. Since that time it has been collected only from the main channel of the Tombigbee River. It is suprising that it has not been taken in the Alabama or lower Cahaba Rivers since the habitat and naiad fauna of these areas were similar. Frierson (1927) did indicate that it was probable that Conrad (1834b) had figured *P. marshalli* under the name *U. mytiloides* Rafinesque (=*Pleurobema clava*, Lamarck, 1819). The specimen figured (Plate 1, Figure 7) by Conrad (1834) as *U. mytiloides* was taken in the Alabama River and may be *P. marshalli*. Based on shell characters it is equally plausible that it represents *Fusconaia ebena* which was abundant in the Alabama River and which *P. marshalli* resembles superficially. Van der Schalie (1939a) reported *P. marshalli* from the upper Tombigbee River at Epes, Sumter County, Alabama.

In recent collections from the upper Tombigbee River, *P. marshalli* was taken from 0.2 miles above the mouth of the Noxubee River (1.4 miles northwest of Gainesville), Sumter County, Alabama, upstream to 0.5 miles above the Mississippi Route 50 bridge (7.3 miles northwest of Columbus), Lowndes County, Mississippi. It was taken at 29 localities between the upper and lower limits of distribution, a distance of approximately 100 river miles. It was most abundant in the downstream section (Gainesville to Warsaw, Alabama) where more than 150 individuals were taken in 10 collections from five localities.

The habitat of Marshall's naiad in the main channel of the upper Tombigbee River was shoals consisting primarily of gravel, and gravel mixed with sand in some areas. Depth in these areas ranged from 0.3 to 1.5 m and current varied from moderate to swift.

Pleurobema taitianum (Lea 1834)
Tait's naiad, Figure 10

Original description--*Unio taitianum*, Plate 4, Figure 11. Lea, I. 1834. "Observations on the Naiades; and Descriptions of New Species of That, and Other Families," Trans. Amer. Philos. Soc. (N.S.), Vol 5, pp 23-119, Plates 1-19.

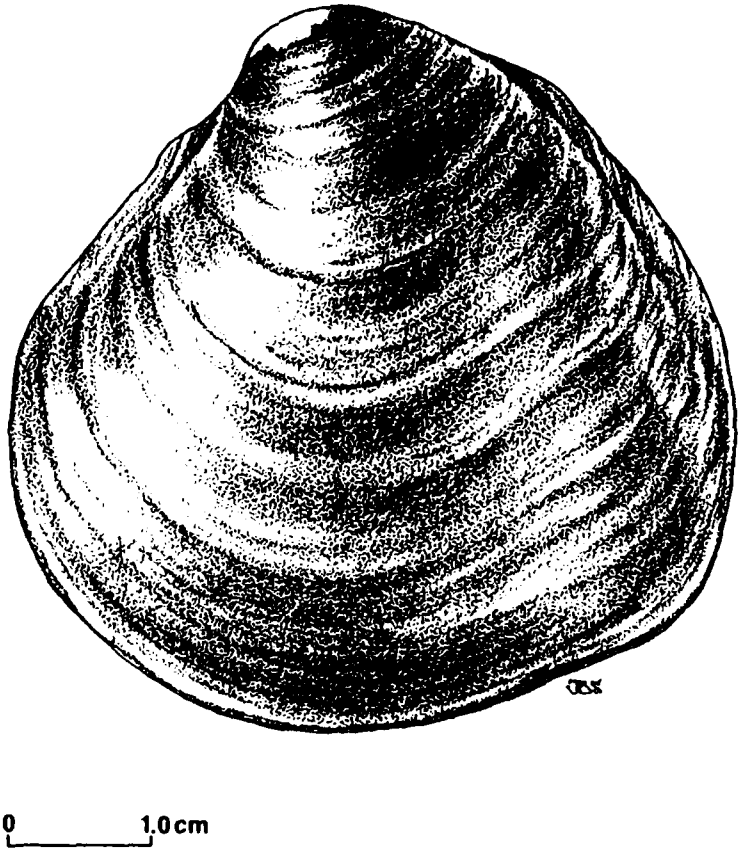

Figure 10. *Pleurobema taitianum* (Lea 1834). USNM 809734. Tombigbee River at Memphis Landing, River Mile 324.4, Pickens Co., Alabama, 24 October 1976

Of the approximately 10 species of *Pleurobema* endemic to the Mobile Basin, *Pleurobema taitianum* is the most distinctive. The shell is triangular in shape, solid and heavy with shallow beak cavities, and white to pink nacre. The color of the periostracum varies from dark brown to black and is usually dull in appearance.

The types of *P. taitianum* were taken from the Alabama River by Judge Tait of Claiborne, Alabama. Tait's naiad occurred in the Alabama River upstream of Claiborne to the vicinity of Selma. The collection from the vicinity of Selma was made in 1933 and is in the Smithsonian Institution (USNM 521324). In 1973, I collected a single specimen of *P. taitianum* from the remains of a clam shell operation and dredge spoil along the east bank of the Alabama River at Claiborne, Monroe County, Alabama. Frierson (1908) described a new species, *Pleurobema tombigbeanum*, based on specimens from Demopolis, Marengo County, Alabama, and Columbus, Mississippi, but later (1927) placed *P. tombigbeanum* in the synonomy of *P. taitianum*. Van der Schalie (1939a), however, continued to recognize both species and reported *P. tombigbeanum* from the Tombigbee River at Epes. In a report on the naiades of the Cahaba River, van der Schalie (1938) reported three collections of *Pleurobema cordatum* and indicated that his specimens may belong to *P. taitianum* and *P. tombigbeanum*. I have examined one collection of *P. cordatum* reported by van der Schalie (1938) from the lower Cahaba River and have determined that it is identical to *P. taitianum* material from the Alabama and Tombigbee Rivers. This constitutes the only known record of this species from the Cahaba River.

There is one collection of *P. taitianum* in the University of Michigan Museum of Zoology labeled "Coosa River, Alabama." This collection was part of the B. H. Wright collection and probably represents a mislabeled specimen (Hurd 1974).

In recent collections from the main channel of the upper Tombigbee River, *P. taitianum* was collected at 17 localities from 1.5 miles above the I-59 bridge (4.5 miles north-northeast of Epes, Alabama) upstream to just below the mouth of Tibbee Creek (4.4 miles northwest of Columbus, Mississippi). The specimens collected 1.5 miles above the I-59 bridge were taken from what appeared to be a preimpoundment midden. *Pleurobema taitianum*, like *P. marshalli*, reached its greatest abundance in the lower section of the upper Tombigbee River between 2 miles north of Gainesville, Sumter County, Alabama, and 0.5 mile east of Memphis, Pickens County, Alabama. Unlike *P. marshalli*, Tait's naiad was absent in collections from just above Pickensville, Pickens County, Alabama, upstream to 3.1 miles west of Columbus, Lowndes County, Mississippi. While *P. taitianum* reached its greatest abundance in the large river habitat in the upper Tombigbee River, two specimens have recently been taken in the lower part of the Buttahatchie River in the vicinity of U. S. Highway 45 crossing north of Columbus. The specimens are in the Mississippi Museum of Natural Science (MMNS 921 and MMNS 929) in Jackson, Mississippi.

The habitat of *P. taitianum* in the main channel of the upper Tombigbee River appears to have been gravel shoals. It was fairly abundant (more than 30 specimens from three collections) at the gravel shoal 2 miles north of Gainesville, Alabama, where the only live individual was taken. The only locality where more individuals were taken (40 specimens from two collections) was a site 5 miles north of Gainesville. These specimens were taken from middens along both banks where the current was moderate but no islands or gravel bars were exposed. Substrate along the shore to a depth of 1.7 m was a mixture of sand and gravel with some clay.

Epioblasma penita (Conrad 1834)
southern comb naiad, Figure 11

Original description--*Unio penitus*, Plate 5, Figure 1. Conrad, T. 1834a. "New Fresh-Water Shells of the United States, with Colored Illustrations, and a Monograph of the Genus Anculotus of Say: also a Synopsis of the American Naiades," Philadelphia, Pa., 76 pp., 8 plates.

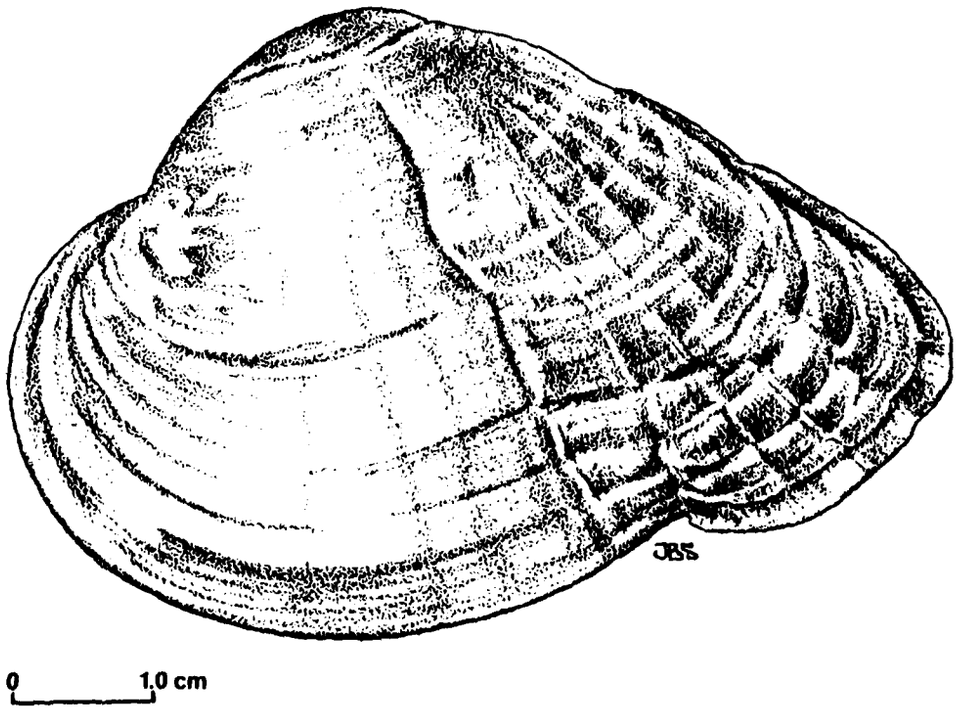

Figure 11. Epioblasma penita (Conrad 1834). USNM 809735. Tombigbee River at Memphis Landing, River Mile 324.4, Pickens Co., Alabama, 24 October 1976

Since the original description of *Unio penitus* Conrad (1834a), this species and other similar species have been assigned to several genera (*Truncilla*, Rafinesque 1819; *Dysnomia*, Agassiz 1832; and *Epioblasma*, Rafinesque 1831). More recently, Johnson (1978) applied the name *Plagiola* (Rafinesque 1819) to this group of strongly sexually dimorphic species of Unionidae. For reasons which are beyond the scope of this work, the genus *Epioblasma* is used in this paper.

Several species of *Epioblasma* have been described from rivers and creeks of the Mobile Basin. Johnson (1978) placed the species *metastriatus*, Conrad 1838 (Black Warrior River, Alabama); *othcaloogensis*, Lea 1857 (Othcalooga Creek, Georgia); *compactus*, Lea 1859 (Etowah and Conasauga Rivers, Georgia); and *modicellus*, Lea 1859 (Conasauga and Chattooga Rivers, Georgia) in the synonomy of *E. penita*. Other workers have recognized one or more named species as valid. For the purposes of this report, *Epioblasma penita* is recognized as distinct from other species of *Epioblasma* described from the Mobile Basin. Additional study of specimens from the Black Warrior, Cahaba, and Coosa Rivers is needed to determine the specific status of the remaining four named species of *Epioblasma*.

The southern comb naiad (*Epioblasma penita*) was described by T. A. Conrad (1834a) from specimens collected in the Alabama River near Claiborne where he reported the species as rare. Lewis (1876) reported *Unio penitus* (Conrad 1834a) from the "Alabama River; Coosa River." In a discussion, Lewis (1876, page 90) reported that "*Unio penitus*, of the Alabama River, is replaced further east (in Alabama and Georgia) by *U. compactus*, a similar but smaller species. It is possible that both these species occur in the Coosa River; but at the present time a doubt is entertained of such occurrences." Based on this comment, it is not clear that Lewis did have specimens of *E. penita* from the Coosa River. In a recent survey of the Coosa River, Hurd (1974) reported *E. penita* from 10 localities in the Coosa System of Alabama and Georgia. These records are based on specimens taken in the main channel of the Coosa River and the lower portion of larger tributaries prior to impoundment. These specimens should be compared to other Mobile Basin *Epioblasma* for confirmation of their identity.

In the Cahaba River, a tributary of the Alabama River, van der Schalie (1938) reported *Dysnomia* (=*Epioblasma*) *metastriata* and *othcaloogensis*. At the same time, he questioned the specific status of *othcaloogensis* and indicated that it was "probably the young male form of *D. metastriata*." He found *E. metastriata* was usually associated with small and medium-sized river conditions and found it only sparingly in the large river habitat below Centerville, Alabama. Van der Schalie (1938) did not report *E. penita* from the Cahaba River. However, there is one female specimen in the Smithsonian Institution (USNM 84472) from the Cahaba River in Perry County, Alabama, collected by Dr. Hartman which is identical to specimens of *E. penita* from the Alabama and Tombigbee Rivers. The Cahaba River in Perry County, Alabama, is similar in size and substrate to the Tombigbee River at the mouth of the

Buttahatchie River north of Columbus, Mississippi. The specimen of *E. penita* (USNM 84472) from the Cahaba was apparently not examined by Johnson (1978).

The southern comb naiad was reported from the Tombigbee River system by Simpson (1900). Van der Schalie (1939a) reported only *Dysnomia metastriata* from the Tombigbee River at Epes, Alabama. I have not examined these specimens but it is very likely that they are *E. penita*. This assumption is based on the absence of *E. metastriata* from recent collections in the upper Tombigbee and the apparent habitat preference of *E. metastriata* for small to medium-sized rivers above the Fall Line.

In recent collections from the main channel of the upper Tombigbee River, *E. penita* was taken at 23 sites from 0.2 mile above the mouth of the Noxubee River northwest of Gainesville, Alabama, upstream to just below the mouth of Bull Mountain Creek, northeast of Amory, Mississippi. It was most abundant in the lower reach from the vicinity of Gainesville upstream to Pickensville. Above Pickensville it occurred less frequently and in smaller numbers. It is also known from one tributary of the upper Tombigbee, the Buttahatchie River. This is a small to medium-sized river with numerous gravel shoals and sand and gravel islands and bars. *Epioblasma penita* occurred throughout the lower 60 miles of the Buttahatchie River and was more abundant toward the mouth of the river (Paul Yokley personal communication). Samples from several other large tributaries of the upper Tombigbee River have not revealed the presence of this species.

The habitat of *E. penita* in the main channel of the upper Tombigbee River was shoals with moderate to swift current. Substrate in shoal areas was predominantly gravel or gravel mixed with sand. The depth of the shoals was variable, ranging from 0.3 to 1.5 m.

Current Conservation Status

One or more of the five species (*Quadrula stapes, Pleurobema curtum, Pleurobema marshalli, Pleurobema taitianum*, and *Epioblasma penita*) discussed herein have been reported as endangered during the past 12 years. Athearn (1970) reported 38 endangered species of the family Unionidae from the Tombigbee, Alabama, and Coosa Rivers, including *Q. stapes, Obovaria (=Pleurobema) curtum*, and *Dysnomia (=Epioblasma) penita*. These three species were also reported as endangered by Stansbery (1971). More recently, Stansbery (1976) reported all five species as endangered in Alabama and indicated habitat alteration was the primary threat to their survival. On 11 April 1980, the U. S. Fish and Wildlife Service published a notice of status review (Federal Register, Vol 45, No. 72, pp 24904-24905) for all five species and requested data on distribution, population trends, and threats. The notice of review cited the construction of the Tennessee-Tombigbee Waterway as the most obvious threat. The river section of this project which involves four

impoundments on the upper Tombigbee from Gainesville, Alabama, to Amory, Mississippi, is almost complete. Three of the dams have been completed and closed with the fourth structure, Aberdeen Lock and Dam, under construction and scheduled to be closed in 1982.

The impact of man-made impoundments on naiad mollusks is generally known. In the early 1900's, Ortmann (1909) pointed out the adverse effects of pollution and dams on the freshwater fauna, particularly mollusks and crustaceans, in western Pennsylvania. The adverse impacts of Tennessee Valley Authority (TVA) impoundments on the naiad mollusks in the Muscle Shoals area of the Tennessee River is perhaps the best documented case. Ortmann (1924) was the first to express concern for the naiad fauna of mussel shoals, the most diverse (approximately 70 species in 31 genera) in North America. Subsequent studies of the Muscle Shoals naiad fauna (van der Schalie 1939b, Stansbery 1964, and Isom 1969) have shown a drastic reduction (approximately 50 percent) in the number of species present. This reduction is attributed almost entirely to the habitat alterations associated with impoundments. Fuller (1974) presents an excellent summary of the impacts of dams on bivalve mollusks. The general impacts of dams and impoundments on the aquatic environment is discussed in Baxter (1977) and Baxter and Glaud (1980).

In addition to the five species discussed above, Stansbery (1976) reported six other naiades, *Pleurobema decisum* (Lea 1831), *Pleurobema perovatum* (Conrad 1834), *Obovaria jacksoniana* (Frierson 1912), *Potamilus inflatus* (Lea 1831), *Medionidus mcglameriae* (van der Schalie 1939a), and *Lampsilis perovalis* (Conrad 1834), as endangered species in Alabama. These species occur in the upper Tombigbee River system. Three species (*P. decisum, P. perovatum*, and *Lampsilis perovalis*) which occurred in the main channel are also known to inhabit tributaries of the upper Tombigbee River in Alabama and Mississippi. Two species (*Obovaria jacksoniana* and *Potamilus inflatus*) have been taken in the main channel of the upper Tombigbee but are not known to occur in tributary streams. These two species also occur in Gulf Coast rivers west of the Mobile Basin in Mississippi and Louisiana. *Potamilus inflatus* was not taken in recent collections from the upper Tombigbee, but it was reported from the Tombigbee River at Epes by van der Schalie (1939a). There is also a series of three specimens in the Smithsonian Institution (USNM 83908) from the Tombigbee River at Columbus, Mississippi. *Medionidus mcglameriae* was described by van der Schalie (1939a) from the two type specimens taken in the Tombigbee River at Epes, Sumter County, Alabama.* The types are the only known specimens of this species.

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* Johnson (1977) in a monograph of the genus *Medionidus* includes descriptive data for *M. mcglameriae* presented by van der Schalie (1939) and comments on a possible relationship of the species.

Conclusions

Historically, the diversity of the naiad fauna of the Mobile Basin was second only to that of the Tennessee River. Today, with all of the major rivers (Coosa, Tallapoosa, Alabama, Black Warrior, and Tombigbee) drastically altered by impoundments and/or channelization, much of the naiad fauna has been eliminated. Prior to construction of the Tennessee-Tombigbee Waterway, the upper Tombigbee River supported a diverse naiad fauna of more than 40 species, including several Mobile Basin endemics. Construction of the Waterway converted a large free flowing river with numerous gravel shoals, islands, and bars into a series of reservoirs. Alteration of riverine habitat in this manner usually results in marked changes in abundance and species composition of naiades and fishes. Most notable among these changes is the reduction of diversity.

In the upper Tombigbee River today, the river bendways in the upper reaches of each impoundment where cutoffs have been constructed resemble preimpoundment conditions. These may be the only viable areas to maintain populations of several naiades endemic to the Mobile Basin. A major problem, however, is the formation of levees or "plugs" across the channels leading into the river bendway at cutoffs. When this happens, the absence of flow through the bendway results in siltation of the river channel behind the levee. After 3-5 years of isolation from river flow, the bendway gradually evolves into an oxbow lake supporting populations of fishes and naiades characteristic of ponds, sloughs, and swamps. The obvious solution to this problem would be to maintain flow through the bendway even if it required annual dredging. An effort to reestablish flow and clean gravel substrate in cutoff areas should be made immediately. The possibility for recovery becomes more difficult and less likely the longer a river bendway is closed off.

In the East Fork of the Tombigbee River above Aberdeen Reservoir, the diversity of naiades (approximately 30 species) was less than in the upper Tombigbee between Gainesville and Pickensville, Alabama, prior to impoundment. As recently as the mid-1970's, however, the East Fork did support populations of several naiades endemic to the Mobile Basin. The canal section of the Tennessee-Tombigbee Waterway which is being constructed parallel to the East Fork has the potential for eliminating the more sensitive naiad species in that stream. All precautions to prevent siltation of the East Fork and its tributaries should be taken. Also, the minimum flow structures (from the canal section) on streams tributary to the East Fork should be constructed in such a way to maintain some semblance of historic water quality with regard to such parameters as flow, pH, temperature, dissolved oxygen, etc. The East Fork is at present the only known habitat for *Pleurobema curtum*.

Beyond the main channel of the upper Tombigbee River, there are several major tributaries in Alabama and Mississippi which support good populations of naiades and fishes. Some of the more important tributaries include the Buttahatchie River, Luxapalila Creek, Sipsey River,

and Noxubee River. Samples taken from three of these streams (Buttahatchie and Noxubee Rivers and Luxapalila Creek) indicate the presence of one or more species of naiades endemic to the Mobile Basin. The remaining stream, Noxubee River, has not been sampled as thoroughly but, based on the limited material available, it appears to support a diverse naiad fauna. In the past, stream channelization has been discussed for portions of all of these tributaries and one, Luxapalila Creek, has been channelized in two areas. The upper part of the Luxapalila Creek, channelized approximately 30 years ago, is showing some signs of recovery. Future channelization projects in all of these tributaries should be avoided since these streams are very important in maintaining populations of endemic naiades and fishes of the Mobile Basin.

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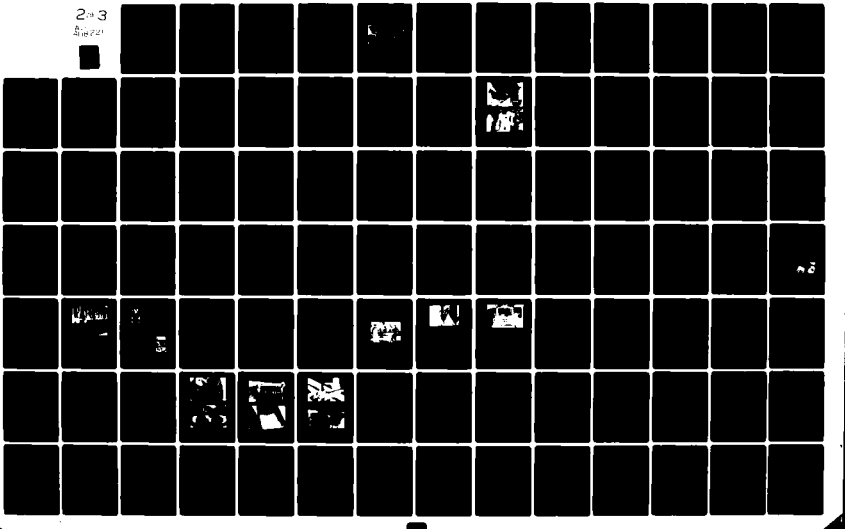

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HABITAT DEVELOPMENT FOR FRESHWATER MOLLUSKS IN THE TOMBIGBEE RIVER NEAR COLUMBUS, MISSISSIPPI

by

Andrew C. Miller*

Abstract

The U. S. Army Engineer Waterways Experiment Station (WES) has begun a project to design and monitor a gravel bar habitat for aquatic insects and mollusks. This bar will be placed in the Tombigbee River near Columbus, Mississippi, river mile 232.9. This study has been divided into three phases: biological evaluation of the project area (to be initiated in the summer of 1981), design of the bar or bars, and subsequent monitoring of the habitat after construction by the U. S. Army Engineer District, Mobile.

Introduction

A diverse biological community depends primarily upon the presence of appropriate habitat. Proper amounts of food, cover, water, minerals, and dissolved oxygen provide impetus for colonization by certain biotic assemblages suited to existing conditions. Plants and animals populating an area are part of a self-regulating system that responds dynamically to natural variations in biotic and abiotic conditions. In the development and operation of a water resources project, aquatic habitats are often converted from one type to another. For example, when a freely flowing river is altered by the construction of an impoundment or a lock and dam structure, species suited to running water are usually replaced by organisms common in slack-water environments. Typically, this means loss of riffle-inhabiting organisms such as darters, mayflies, stoneflies, and unionid mollusks and an increase in numbers of sunfishes, free-swimming insect larvae such as *Chaoborus*, and plankton. Construction and operation of the Tennessee-Tombigbee Waterway (TTW), which includes lock and dam structures, channel maintenance, and a canal between the Tennessee and Tombigbee Rivers, will result in the conversion of large amounts of a free-flowing river to a slack-water habitat.

The TTW was authorized by Public Law 525 in accordance with recommendations contained in House Document 486 of the 79th Congress. This project extends from Demopolis, Alabama, on the Tombigbee River to mile 215 on the Tennessee River near the common boundary of Tennessee, Mississippi, and Alabama. Development of the TTW includes removal of about 260 million yd^3 of soil and construction of five lock and dam

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structures on the river. One hundred and ninety miles of free-flowing stream will be modified to form a series of run-of-the-river reservoirs, and approximately 20 miles of oxbow lakes will be formed by bendway cutoffs. When completed, the project will provide a shortened route between the eastern gulf coast and the central United States. In addition to economic, cultural, and sociological impacts, the TTW will cause habitat loss, development of habitat, and conversion from one type of habitat to another.

The U. S. Army Engineer Waterways Experiment Station (WES) will design a gravel bar habitat for a site near Columbus, Mississippi, on the Tombigbee River. When an appropriate design is prepared, the U. S. Army Engineer District, Mobile, will construct the habitat. The intent of the bar is to provide habitat for darters, certain aquatic insects, and unionid mollusks indigenous to the free-flowing Tombigbee River. This project has two objectives: partial mitigation of losses of running water environments on the Tombigbee River caused by the TTW, and better understanding of problems associated with design and construction of artificially placed natural substrate material for aquatic organisms. Information obtained from the second objective should have application to other water resource projects in the United States.

Area of Study

This work will take place in the old river channel of the Tombigbee River, directly below the Columbus Lock and Dam at river mile 232.9, Columbus, Mississippi (Figures 1 and 2). The Columbus damsite is located in northeast Mississippi on the Tombigbee River approximately 149 miles above the confluence of the Warrior River. The river above Columbus has a drainage area of 4470 square miles, is about 85 miles in length, and has an average width of 50 ft or less. This river is within the Coastal Plain which has elevations ranging from 1000 to 126 ft msl at the dam. The Columbus Lock and Dam structure at Columbus, Mississippi, is one of the five lock and dams developed as part of the TTW. This dam was completed in January 1981, and the lock and dam became operational for navigation traffic by the summer of 1981.

The Tombigbee basin has a temperate climate with long warm summers and short mild winters. The normal annual temperature, based on records from six stations in the basin, is approximately 63°F. Monthly normals range from 45° in January to 81° in July. The average normal annual precipitation in the area is 52 in. March is usually the wettest month (6 in.) and October (less than 3 in.) the driest month (U. S. Army Engineer District, Mobile 1972). For the period of record (October 1899 to December 1912, August 1928 to present) the average discharge (63 years) was 6458 ft^3/s. Table 1 presents discharge data from 1975 to 1978 (U. S. Geological Survey 1975-1978).

Water quality at Columbus, Mississippi, is generally good. Based on data collected in 1978 the water is fairly soft; hardness ranged from

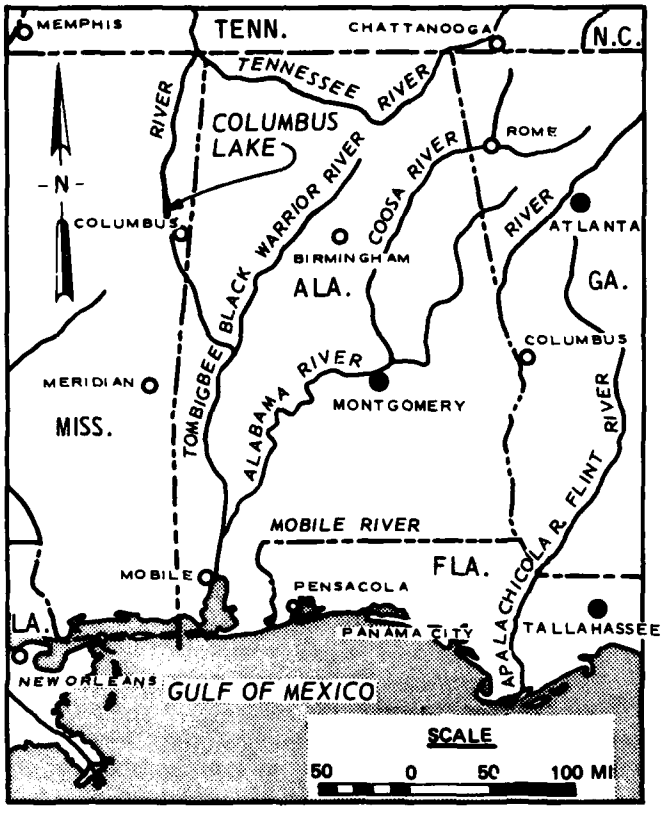

Figure 1. Vicinity map, Tombigbee River in Mississippi and Alabama

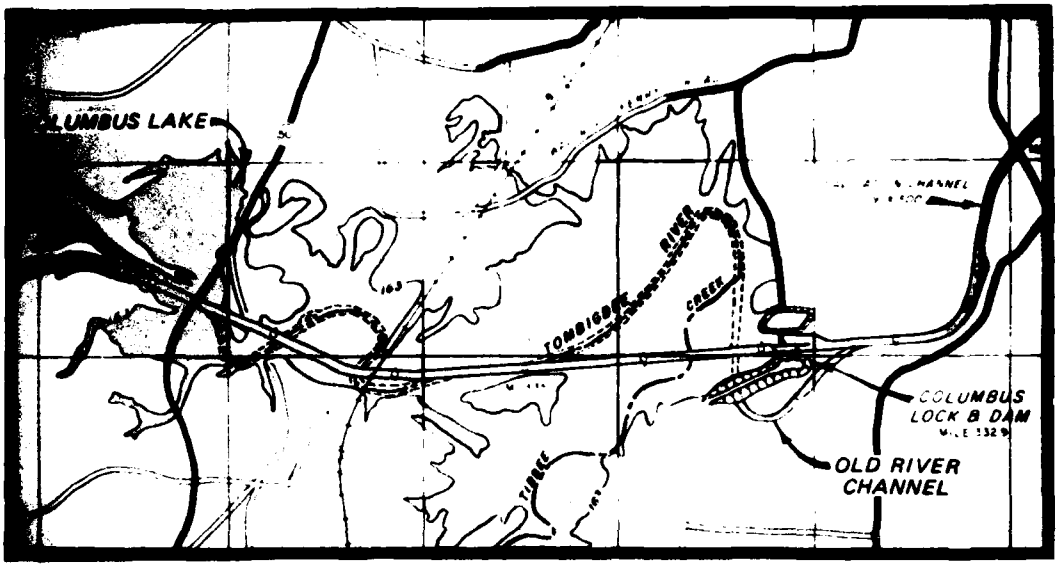

Figure 2. Columbus Lake on the Tombigbee River, Mississippi

34 to 55 mg/ℓ as $CaCO_3$ and total alkalinity ranged from 24 to 38 mg/ℓ as $CaCO_3$. Specific conductance (81-140 micromhos), dissolved sulfate (6.3-9.8 mg/ℓ), dissolved residue (56 to 88 mg/ℓ), and turbidity (10-19 JTU) were at moderate levels. Dissolved oxygen and 5-day biological oxygen demand ranged from 7.8 to 9.5 mg/ℓ and 2.6 to 4.5 mg/ℓ, respectively (U. S. Geological Survey 1978).

Table 1

Total, Mean, Maximum, and Minimum Discharge Values (cfs) for the Tombigbee River at Columbus, Mississippi, Water Years 1975-1978

Water Year	Total	Mean	Maximum	Minimum
1975	3,589,475	9,834	115,000	820
1976	2,453,300	6,703	36,100	660
1977	2,266,463	6,209	75,300	269
1978	2,590,258	7,097	66,300	570

The Tombigbee River at Columbus has provided habitat for a unique assemblage of unionid mollusks. Hinckley in 1906 identified 39 species, van der Schalie in 1939 identified 37 species, and Williams and Stansbery (1972) collected 35 species of naiads from this area. All of the status review species (*Quadrula stapes, Pleurobema curtum, Pleurobema marshalli, P. taitianum*, and *Epioblasma penita*) have been collected at Columbus or within the immediate vicinity of Columbus (Stansbery 1980).

Approach

The study has been divided into three separate phases. These include initial field evaluation of the project area, design of the habitat, and subsequent monitoring and possible seeding of the bar with mollusks. The actual construction of the bar will be the responsibility of the Mobile District. It is the intent of this study not only to design the habitat, but also to judge its success and potential application to other areas of the country. The three phases of the project are described below.

Phase I

A background study of the biota and selected water quality parameters in the area of Columbus will be undertaken. Approximately 10 miles of the river below the lock and dam will be evaluated using aerial photographs and maps. During a period of low water in the summer of 1981, a field party in a small boat will survey the river to look for

naturally occurring gravel bars or riffles. The locations of these bars and their approximate size will be recorded.

To the extent possible, one or two naturally occurring gravel bars in the river, judged to be similar in size and character to that planned for development, will be chosen for further studies. The following activities will be conducted at each area during low-flow conditions:

a. Each naturally occurring gravel bar will be subdivided into equally sized subunits using a grid system. All physical features (configuration, water depths, exposed rocks or logs, emergent vegetation, etc.) will be recorded on a gridded map. Distances will be measured using a steel tape or other appropriate means.

b. A minimum of 12 sediment samples will be collected from the existing bar or riffle using a Ponar grab sampler. Sample sites will be randomly chosen within various substrate types (if they exist) and the location of each recorded on the map. Sediment samples will be returned to the laboratory for analysis of particle-size distribution.

c. At each of the sites where sediment was collected, triplicate benthic samples will be taken using an appropriate sampler. Samples will be sieved through a 0.5-mm-mesh screen in the field and preserved in 70 percent ethyl alcohol. All organisms will be identified to species level or the lowest possible taxonomic level using appropriate keys.

d. If appropriate, a 10-ft wooden brail bar with four-prong hooks will be used for qualitative sampling of the immediate vicinity of each bar for unionid mollusks. The brail will be towed with the current by a small boat operated at a slow rate of speed. The entire gravel bar will be sampled. Specimens will be removed from the hooks and, if possible, identified to species while still alive and then replaced in the substrate by hand. If necessary, specimens will be sacrificed for identification by examining internal shell features and soft parts. The approximate location of the mollusks collected will be recorded on the map.

e. A water sample (or samples) will be collected from each site. Samples will be preserved in the field and analyzed in the laboratory according to specifications outlined in Standard Methods for the Examination of Water and Wastewater (American Public Health Association). Parameters to be determined include turbidity, total alkalinity and hardness, dissolved calcium, magnesium, sodium, potassium, total suspended and dissolved solids, nitrate, sulfate, and phosphate. Dissolved oxygen, pH, water temperature, specific conductance, total hardness, and alkalinity will be determined in the field.

Phase II

Upon completion of the Phase I studies, a plan for a man-made gravel bar in the old river channel at mile 232.9 will be developed and furnished to the Mobile District for review and execution. The plan will, to the extent feasible, reproduce the natural requirements isolated in the Phase I studies.

Preliminary indications are that some channel restrictions may be required to increase the flow in the river channel. These will have to have enough current above the substrate of the bar to adequately flush sediments deposited during high water. However, the habitat must be designed so that it is not eroded during high flow. A simple method for increasing flow would be to construct a small levee partway across the river at a specified site or sites. Possibly, more than one bar can be placed in the channel depending upon conditions of flow.

Phase III

Initiation of this portion of the work is dependent upon successful construction of the habitat. Once in place, the gravel bar will be monitored regularly, at least twice a year (in the spring and once in the late summer) during periods of low flow. The purpose of these studies will be to assess the integrity of the gravel bar and to document colonization by aquatic organisms. The following studies, using the procedures outlined in Phase I, will be conducted:

a. Any discernible features (excessive sedimentation, plant growth, etc.) on the bar or in the immediate area will be noted and recorded on color film. All notable items will be located on a gridded map or drawing, using the same procedure outlined above.

b. Twelve sediment samples will be collected for particle-size distribution analysis. Sample sites will be chosen according to methods employed during Phase I.

c. At least 12 triplicate benthic samples will be taken from each sediment-sampling site for identification of macroinvertebrates.

d. Water samples will be collected from the gravel bar site, preserved in the field, and analyzed in the laboratory according to specifications stated in Standard Methods (American Public Health Association).

e. If deemed necessary, the area will be brailed for mollusks. It is recognized that colonization of mollusks from glochidia to catchable size can take several years. However, there is the possibility that mollusks may be carried from other areas by the current or can be brought to the area by other methods.

f. Two years after placement, WES will seed the gravel bar with one or more species of mature unionid mollusks. Seeding will be done only if the newly placed habitat is stable, is relatively free of suspended material, and has been colonized successfully by invertebrate fauna. Species suited for transplanting should be common Tombigbee River forms; *Fusconaia ebena* or *Quadrula* sp. are likely choices. However, the final decision as to which species to seed will be based upon existing conditions on the bar and the river. The unionids will be collected from a site close to Columbus, identified, tagged, and placed at specific sites in the substrate by hand. The procedures for collecting, marking, and relocating the mollusks will be based upon methods used in a relocation study conducted in the Upper Mississippi River (Oblad 1979). After this initial work, the success of these mollusks will be checked at least twice a year as part of the Phase III program. If transplanting these unionids is successful, consideration will be given to seeding the bar with some of the more uncommon unionids, particularly the status review species.

Summary

The purpose of this study is to design a gravel bar habitat for use by riffle-inhabiting aquatic organisms such as darters, mayflies, stoneflies, and unionid mollusks. Design will be based upon engineering and hydrologic considerations as well as physical and biological characteristics of similar areas on the Tombigbee River near Columbus, Mississippi. A fairly complete census of the biota at two existing riffles or bars will be made to establish the types of organisms likely to colonize the artificially placed substrate. Following placement of the habitat, a monitoring program will be instituted. These studies, to be conducted twice annually for at least 5 years, will document physical features and invertebrate colonization rates at the artificially placed bar. If deemed appropriate, the new bar will be seeded with one or more species of bivalves. This latter work will be conducted to assess the possibility of ultimately transplanting indigenous federally listed (or very uncommon) threatened or endangered unionid mollusks.

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Discussion

M. Koryak - Could the levees proposed as part of the gravel bar study be vegetated with water willow?

A. Miller - Probably not. The water levels fluctuate too much and water willow would not grow successfully at the site of the gravel bar study.

R. Whiting - On what authority does the Mobile District expend funds for habitat creation for mollusks in the Tombigbee River?

J. Mallory - The TTW was authorized in 1946. There were no funds for mitigation. However, it is the desire of the Mobile District to provide the best possible project for fish and wildlife as well as for navigation. Gravel substrate is not abundant in the Tombigbee River; if we can successfully develop a gravel bar habitat at Columbus, it might work in other parts of the river.

CUMBERLANDIAN MOLLUSK CONSERVATION PROGRAM

by

John J. Jenkinson*

Introduction

During its nearly 50-year history the Tennessee Valley Authority (TVA) has undertaken a wide variety of projects dealing with freshwater mussels and, recently, aquatic snails. The Cumberlandian Mollusk Conservation Program (CMCP) is a recent addition to the list of molluscan projects and, perhaps, is the most wide-ranging. In one respect or another the CMCP is analogous or homologous to many of the molluscan studies being conducted by various offices of the Corps of Engineers. This introduction to the CMCP covers the evolution of the program, describes the ongoing and proposed activities and, hopefully, presents enough details about what TVA is doing so that other biologists studying freshwater mollusks will be able to profit from our experience and avoid our mistakes. A brief description of this program has been published previously (Jenkinson 1981). Neither of these presentations necessarily reflect the views and policies of TVA.

Program Evolution

During the mid-1960's, residents of the Duck River basin in central Tennessee requested that TVA study the feasibility of a series of recreational and water supply reservoirs in this watershed. Continued local interest resulted in the establishment of the Duck River Project which consisted of two reservoirs: a 3,230-acre impoundment in the headwaters of the Duck River at Normandy and a 12,600-acre impoundment in the middle of the length of the river at Columbia. Normandy Reservoir was to be built first and it was completed in 1976. Work on Columbia Dam started in 1973 but was essentially halted in 1977 with construction 35 percent complete.

Throughout the construction of both Normandy and Columbia Reservoirs, malacologists and others had been loudly protesting the impoundment of the Duck River. From a relatively early time, the Duck River had been known to support an extremely diverse aquatic fauna, including several snail species and 65 species or forms of freshwater mussels (Ortmann 1924). The conversion of 17 miles of the headwaters and 54 miles of the middle of the Duck River to impoundments was argued to have a substantial impact on the native fauna, much of which existed only on riffles (shoals). In the case of the freshwater mussels this situation was aggravated by two additional factors: there had been a

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substantial decline in all mussel stocks in the upper Duck River between 1965 and 1972 (the cause of which has never been determined) (van der Schalie 1973), and a large number of the species were only known to occur in the upper 150 miles of the river--the reach in which both impoundments were to be built.

When Ortmann published his study of the Duck River (1924), he discussed at some length the discontinuous distribution of some freshwater mussel species in this and adjacent river systems. Ortmann recognized 45 species or forms to comprise a Cumberlandian faunal group which he defined to be those species whose ranges are restricted to the Cumberland and Tennessee River systems but excluding the lowermost sections of both rivers. This faunal group he contrasted with at least two others in the interior basin: The Ohioan species--those which occur in the larger part of the Mississippi River drainage outside of the Cumberlandian area--and the species of undetermined origin--those which occur in nearly all of the major stream basins in the Mississippi system, including the Cumberlandian region.

With regard to the downstream limits of the Cumberlandian fauna, Ortmann (1925) noted that Clarksville, Tennessee, was near the limit on the Cumberland River and that there was an obvious faunal shift between Columbia and Centerville on the Duck River. He speculated that such a limit would be found on the Tennessee River somewhere below Muscle Shoals, Alabama. Ortmann presented no explanation of why these limits should still exist; however, he interpreted the shift in faunas to represent previous separations of the drainage basins. Later workers have extended Ortmann's faunal concepts to a continental scale (van der Schalie and van der Schalie 1950) and have adjusted the limits of the Cumberlandian faunal area (Isom and Yokley 1968a), but they generally have confirmed that this fauna is distributed within finite limits that do not include entire (present) drainage basins (Isom and Yokley 1968b and van der Schalie 1973).

All of this is indirectly pertinent to the Columbia Dam Project because the Cumberlandian freshwater mussel fauna has been inpacted substantially by human activity in the Tennessee and Cumberland River watersheds. Both of the major rivers have been impounded throughout much of their lengths, impoundments also are common on many tributaries, and many of the free-flowing streams have been impacted by agricultural, mining, and industrial activities. These aquatic impacts, when applied to mussel species with small geographic ranges and narrow habitat requirements, have severely depressed the populations of most Cumberlandian species. A number of mostly large river species are already extinct and 13 Cumberlandian species have been placed on the U. S. Fish and Wildlife Service list of endangered and threatened species. Seven of these thirteen species have been reported from the upper Duck River; however, only two appear to be alive in the river at present. Recent TVA surveys have confirmed that the birdwing pearly mussel, *Conradilla caelata* (Conrad 1834) (=*Lemiox rimosus* (Rafinesque 1831)), is relatively abundant in a 30-mile reach of the Duck River and that the Cumberland

monkeyface pearly mussel, *Quadrula intermedia* (Conrad 1836), is rare in essentially the same reach of the Duck River. The reach in which both of these endangered species occur is entirely within the 54 miles to be impounded by Columbia Dam.

In 1977 the U. S. Fish and Wildlife Service issued a Biological Opinion stating that completion of Columbia Dam would be likely to jeopardize the continued existence of these two mussel species. Later that year, the Office of Management and Budget asked TVA to examine alternatives to completing Columbia Dam as originally proposed that would not jeopardize the endangered species yet would provide the project benefits. The report on that study (TVA 1979) found the two alternatives studied to be unacceptable but, in its description of the project as planned, outlined a conservation program that could be implemented for the endangered species as well as the rest of the Cumberlandian mollusk fauna. This conservation program concept was accepted by the Fish and Wildlife Service and incorporated as part of a reasonable and prudent alternative in their revised Biological Opinion on Columbia Dam. A significant constraint associated with this alternative is that the conservation program for the two endangered species must be proved successful before the reservoir can be filled.

Program Description

The revised Biological Opinion was issued in September 1979. At approximately that same time TVA biologists and engineers were preparing a preliminary conservation program work plan. After discussions with the Fish and Wildlife Service a revised set of Cumberlandian Mollusk Conservation Program work plans was prepared in April 1980 (TVA 1980). Implementation of some activities described in the work plans began in the late summer of 1979 and considerable work on most identified activities was under way by the summer of 1980.

As it is being implemented, the program is divided into two time-separated phases with a number of more-or-less separate activities in each phase. The first, or research, phase of the program is designed to accumulate information on the present distribution, life history, and ecologic requirements of the Cumberlandian freshwater mussel fauna, as well as to compile ecologic information on a number of sites which could receive transplants from the Duck River. The second, or conservation, phase of the program is intended to use the information gathered by the research phase activities to enhance populations and communities of Cumberlandian species wherever they occur in the Tennessee River system.

Research Phase Activities

An early research phase activity was to update distribution

information for the Cumberlandian species that occur in the Tennessee River system. This update was required because nearly all published reports on this fauna were 10 or more years old; those surveys were often not extensive, and little or no quantitative information had been taken. The CMCP surveys were designed to correct all three of these deficiencies. Stream reaches to be surveyed were chosen based upon the likelihood that they still might contain populations of Cumberlandian species. Where possible, each selected stream reach was floated throughout its length by one or more survey crews. At each site that appeared to be suitable mussel habitat, the survey crews used hand picking, noodling, snorkel, and, where required, scuba techniques to qualitatively examine the resident mussel populations. When diverse mussel communities were located, these areas were sampled quantitatively using an area-weighted number of 1/4-sq m-quadrat samples. In 1979 and 1980 these techniques were used in reaches of Copper Creek (Clinch River System) and the Powell, Clinch, Nolichucky, Paint Rock, Elk, Duck, and Buffalo Rivers. Reports on all of these stream surveys are either complete or are in preparation. (A 1977-78 TVA scuba survey of selected sites throughout the length of the mainstream Tennessee River indicated that few Cumberlandian species persist in this series of impoundments.)

Two research phase activities deal with the fish species that serve as temporary parasite hosts for larval mussels. In one activity TVA biologists used a variety of sampling techniques to examine the fish communities at a number of sites on each of three streams which contain populations of *Conradilla caelata, Quadrula intermedia*, and other Cumberlandian species. Their purpose was to compile a list of fish species common to all three rivers that would more than likely include the hosts for these and other shared mussel species.

Experiments to actually determine the fish hosts are being conducted at two laboratories located along the Duck and Clinch Rivers. In these facilities local fish are infected with glochidia from locally acquired mussel specimens. The infected fish are maintained in once-through river water to determine if successful transformation of the larval mussels occurs. During the 1980 field season, when only the Duck River laboratory was in operation, the TVA staff identified two species of sunfish, *Lepomis megalotis* (Rafinesque 1820) and *L. cyanellus* (Rafinesque 1819), to be hosts for *Carunculina moesta* (Lea 1841) (=*Toxolasma lividus lividus* (Rafinesque 1820)) and a darter species, *Etheostoma zonale* (Cope 1868), to be a host for *Conradilla caelata*.

Another research phase activity is an attempt to recreate a mussel transformation technique that was used successfully by the U. S. Bureau of Fisheries in the late 1920's. At that time Dr. Max M. Ellis apparently perfected a technique for producing juvenile freshwater mussels without using any fish host. This technique was used by the Bureau to stock thousands of young mussels in parts of the Mississippi and other rivers; it was described by Ellis in scientific papers (Ellis and Ellis 1926, 1927 and Ellis 1929); but it was never presented in sufficient detail to facilitate duplication of his work. Knowledge of such a

procedure today could be of considerable value in salvaging a species so close to extinction that no work is possible on fish hosts or habitat requirements. Glochidial culture could be used to produce enough specimens for life history and ecologic studies and, potentially, for seeding in habitats where the species might survive. There are also a number of commercial applications for such a technique if it could be perfected.

Progress on this rediscovery effort appears promising. During June 1981, one group of glochidia in culture began developing adult mussel anatomical features, including flexing muscles and beating hearts. If this potential breakthrough can be carried to completion and can be repeated with other mussel species, this salvage and propagation tool may become available to freshwater malacologists. At the moment we are encouraged.

Four research phase activities all deal with a set of 15 designated study reaches scattered across the Tennessee Valley. These reaches were chosen for study either because they contain populations of Cumberlandian mussel species, including the two endangered species, or because they were considered likely to accept transplanted mussels from Columbia Reservoir. Each study reach consists of a 200-m length of stream in which there is at least one area of gravel substrate that is known or is likely to be good mussel habitat.

The analysis of these sites was separated into the four activities based upon the principal physical or biologic components. One activity deals with the geomorphology of each reach; one with the characteristics of the water; another with the plankton, periphyton, and macrophyte communities; and another with the benthic insect, fish, and mollusk communities. The charge to each of these activities is to compare and contrast the 15 study reaches from the point of view of that physical component or biologic community.

For the geomorphic study, the reaches are being mapped and data are being collected on channel configuration, substrate composition, particle size distribution, and flow characteristics. These parameters will be analyzed to compare substrate stability and other geomorphic characteristics that could affect resident mussel populations. An adjunct study will explore the effects of low dams and similar structures on substrate stability as they relate to downstream mussel habitat.

The water quality activity includes the collection of a set of sediment samples and monthly surface water samples both to be analyzed for a broad spectrum of materials, including metals and pesticides. Water and wastewater surveys also are being conducted in some basins. These present-day data points will be augmented with existing records from the vicinity of many study reaches. The characterizations of each study reach derived from these data will provide information on the acceptable ranges of tolerence of Cumberlandian species to water-related factors and whether these ranges are exceeded at any of the potential transplant sites.

In the microfauna and floral study, monthly samples of the plankton and periphyton communities are being taken and analyzed both qualitatively and quantitatively. Maps are being prepared for the macrophyte communities that occur at some sites. Comparisons of these data between study reaches may reveal substantial biologic differences not apparent in the physical parameters and may also show correlations between mussel species and components of these communities.

Similar comparisons and correlations will be derived from the macrofauna analysis. In this study, fish populations are being examined three times during the spring and early summer; benthic insect populations have been sampled quarterly throughout a full year; and resident mussel populations are being surveyed and mapped. The mussel data will provide interesting insights into habitat preferences of the various species and general characterizations of the suitability of various habitat types. The fish data will include whether known or suspected fish hosts occur at potential transplant sites. Both of these data sets, as well as that from the insect work, also offer other criteria which will be used to compare study reaches.

The final activity in the research phase of the program will serve to integrate much of the previously accumulated information. This combined analysis will seek to correlate the geomorphic, water quality, and biologic data to characterize the habitats of various Cumberlandian freshwater mussel species and to select those potential transplant sites that are most likely to support transplants from the Duck River. This determination of most suitable transplant sites is scheduled to occur by October 1982, at which time the research phase of the program will end.

Conservation Phase Activities

The conservation phase of the program is intended to utilize the information acquired by the research phase activities to enhance populations of Cumberlandian species wherever they occur in the Tennessee River system. Originally, conservation phase activities were scheduled to be designed and implemented after the research phase analyses had been completed. In actuality, however, some conservation phase activities are already under way.

The single conservation phase activity that was specifically mentioned in the work plans was the transplantation of Duck River Cumberlandian mussel species, especially *Conradilla caelata*, to suitable sites outside the Columbia impoundment area. This activity cannot be implemented until the selection of the transplant site (or sites) has been made and has been accepted by the U. S. Fish and Wildlife Service. Present plans call for the initial transplants to be made during the fall of 1982 and for a semiannual monitoring program to remain in effect until success or failure of this activity has been proven.

All other conservation phase activities relate to enhancement of existing mussel populations either by physical modification of the streams and their watersheds, or by modifications to regulations, operating procedures, and other indirect impacts to the streams and their biota. Most of these activities have not been planned in detail because some proposals could cause considerably more harm than good should they be based on faulty assumptions and because so much new information is being gathered in the research phase of this program which could correct or replace faulty assumptions if they exist.

One potentially detrimental enhancement measure being considered is the construction of mill dams or similar structures. Considerable field experience suggests that these run-of-the-river dams are often just upstream from well developed gravel riffles which frequently contain large populations of many mussel species. If the analyses involved in various research phase activities indicate that mill dams create and maintain riffles, or affect the water or biota in some way that enhances mussel populations we would give serious consideration to installing appropriate structures in a few selected locations. Other proposed structural enhancement measures that may involve similar problems include assisting in the completion of secondary (or alternative) sewage treatment facilities, building silt detention structures on small tributaries in rapidly eroding areas, and installing gabions or similar devices in stream reaches with unstable substrates.

Proposed habitat restoration activities that involve indirect stream or watershed impacts are considerably more varied; however, many of these ideas are unified in that they involve making some segment of the local or regulatory community more aware of the presence and unique nature of the Cumberlandian mollusks, including the endangered species. The results of our recent distribution surveys and the observations made by field crews during these surveys already are being made available to regulatory, management, and development agencies. Judging by our increased interaction with these agencies, this information is beginning to have an effect on impacts to area streams and their watersheds. We intend to offer similar use of the information from our ecologic and life history studies once they are completed.

The geomorphic, water quality, and biologic information now being collected is expected to show correlations between some mussel species and some physical or biologic factors. There may be enough economic or scientific interest in some of these suggested relationships to warrant further evaluation. We intend to identify as many correlations as possible and may decide to study some of them "in house." In any event, we would be willing to cooperate with any research group interested in pursuing these or similar lines of research.

Summary

The preceding paragraphs have attempted to describe the evolution, scope, and level of detail involved in the TVA Cumberlandian Mollusk Conservation Program. By this point it should be apparent that this program can be viewed from a number of perspectives depending upon the interests of the observer. For those interested in the completion of projects like Columbia Reservoir, the program offers a potential solution for a project-threatening endangered species conflict. For those interested in the preservation of endangered species or the Cumberlandian freshwater mussel fauna, the program offers substantial mitigation for another impoundment--including habitat enhancement measures in a variety of Tennessee Valley streams. For a wide variety of aquatic resource assessment and management interests, the program offers a vast data bank that will be available for analysis from numerous perspectives. And for freshwater malacology, the program offers an in-depth analysis of the life histories and ecologic relationships of a major faunal assemblage.

None of these possibilities are of minor importance to those of us involved in the work; we are keenly aware of the unique opportunities this program presents. While the next few years will demonstrate how well we succeed in accomplishing the Columbia Dam-related goals of the program, the field and laboratory accomplishments already made, combined with the educational program now under way, indicate that freshwater malacology and the Cumberlandian mollusk fauna already have started to benefit from our efforts.

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RELOCATION OF *LAMPSILIS HIGGINSI* IN THE UPPER MISSISSIPPI RIVER

by

David Nelson*

This is a case history of a relocation of a Federally endangered mussel, Higgin's Eye Pearly Mussel (*Lampsilis higginsi*) in Sylvan Slough of the Upper Mississippi River at Moline, Illinois. This work was conducted under the direction of the Omaha District, Corps of Engineers, but was located within the administrative boundaries of the Rock Island District. I monitored the project as a representative of the Rock Island District.

The project required the construction of a new bridge from the Rock Island Arsenal (on Arsenal Island) across Sylvan Slough to Moline, Illinois, and the removal of the old bridge.

Omaha District contracted with Ecology Consultants, Inc. (1977), for a brail survey of Sylvan Slough. Higgin's Eye was discovered during this survey.

In accordance with recommendations of the U. S. Fish and Wildlife Service, a second contract was let by the Omaha District to relocate the mussels from the proposed sites of the new bridge piers. The contractor, NUS Corporation, relocated approximately 7000 individuals taken from the two 40- by 70-ft (12.2- by 21.4-m) areas (Oblad 1980). Of these individuals, 3 Higgin's Eyes and 16 Spectacle Cases (*Cumberlandia monodonta*) were discovered. Each Higgin's Eye and Spectacle Case was tagged with embossing tape attached to monofilament (Figure 1). A hole was drilled in the shells near the margin in a postventral position so as not to disturb the attachment of the mantle to the pallial line in back of which the shell's nacre is deposited (Stansbery 1980). The monofilament was then tied to the hole. In addition, 100 common mussel specimens were marked with fluorescent orange spray paint to aid in locating the tagged specimens.

The marked specimens were relocated into the same mussel bed from which they had been removed, approximately 1/4 mile upstream from the proposed bridge site. Two cinder blocks with a rope tied between them were placed about 50 ft from and parallel to the shoreline. The mussels were placed along the rope into the substrate by the divers (Figure 2). The tags were placed under the substrate so they wouldn't be waggling in the current (Stansbery 1980).

The following year (September 1979) the relocation site was revisited and the divers looked for the marked mussels. Within 20 to 30 min

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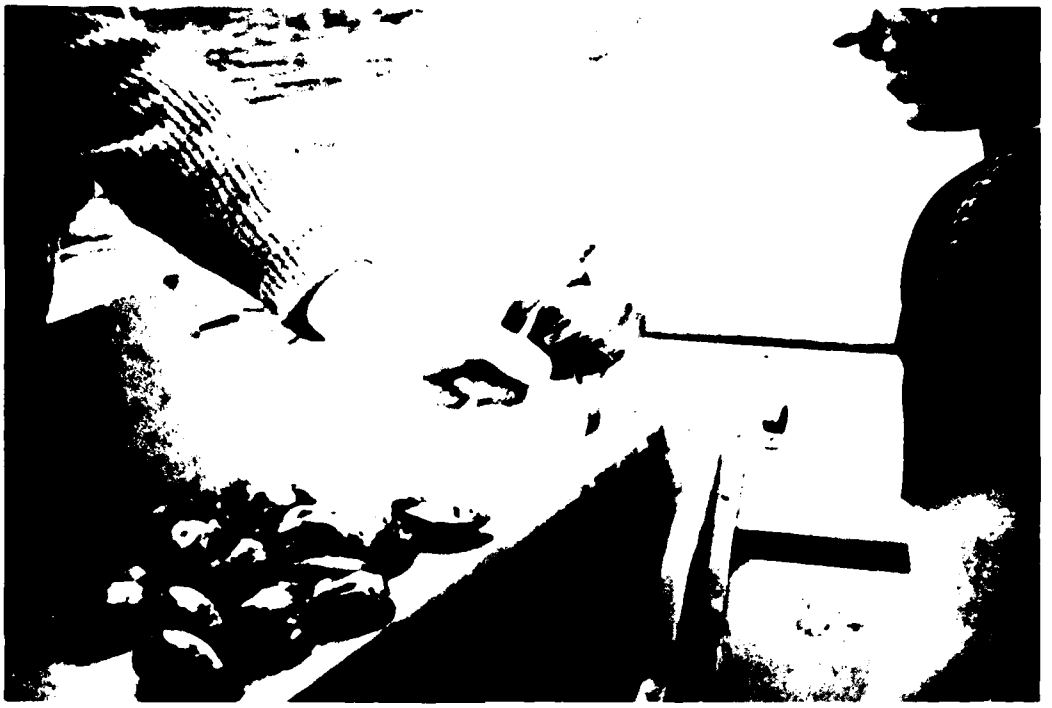

Figure 1. Identification of Higgin's Eye and Spectacle Case

Figure 2. Divers placing mussels

the divers began to bring up the specimens. Of the specimens recovered, 30 of the 50 painted washboards (*Megalonaia nervosa*), 10 of the 50 painted three ridges (*Amblema plicata*), 3 of the 3 tagged Higgin's Eyes, and 11 of the 16 tagged Spectacle Cases were found alive and in good condition.

The diver (C. David Norman), an experienced commercial clammer, was able to distinguish the different species by feel in the murky water with zero visibility. One specimen he brought to the surface in his wet suit vest so closely resembled a Higgin's Eye that photographs of it were sent to Dr. David Stansbery for verification. Higgin's Eye is morphologically variable and sometimes difficult to identify even with a specimen in hand. Dr. Stansbery felt reasonably sure that the specimen was a mucket (*Actinonaias ligamentia carinata*), a species which is morphologically similar to Higgin's Eye. I have pointed out this incident because biologists often ignore a group of individuals who have a great deal of knowledge about mussels, the commercial clammers. They are a valuable resource that we can not afford to overlook.

In conclusion, this effort demonstrated that relocation of endangered mussels is a viable alternative but it only serves to save the individuals and does not save the habitat which is irreplaceable. In addition, the study did not document the long term well-being of the individuals or whether the relocated species were able to sustain recruitment. Mussels should be relocated only after all other alternatives have been exhausted and the remaining choice is to relocate or lose the mussels. If you become involved in a relocation effort, gather as much biological data as can be provided by the relocation project. This information may provide us with knowledge on how to better manage and protect these species and maybe somehow will help to offset the loss of habitat.

I gratefully acknowledge Dr. Bryant Oblad who gave permission to excerpt the above information from his paper. For additional details refer to his paper and others listed in the reference section.

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Discussion

Question: What was the sex of the recovered Higgin's eye mussels?

D. Nelson: Two males and one female.

Question: Are there plans to continue the study?

D. Nelson: There are no further study plans.

Question: How deep was the water?

D. Nelson: It was about 15 ft deep and the substrate was sand and gravel.

P. Yokley: In my opinion, it would take a minimum of 8 to 10 years to see if transplanting mollusks was successful. It would take that long to see if viable offspring had been produced.

D. Nelson: I agree.

HIGGINS' EYE MUSSEL RECOVERY PLAN: PROBLEMS AND APPROACHES

by

Edward M. Stern*

The U. S. Fish and Wildlife Service has established approximately 70 recovery teams that are involved with work on endangered species. Very few of these teams are working on invertebrates, a group of animals that, for the most part, are much more poorly known than vertebrates. There is only one team working with bivalve mollusks, even though there are currently 25 endangered species. The Higgins' Eye Team, as established by the U. S. Fish and Wildlife Service, includes individuals representing a wide diversity of interests and expertise. Included are a malacologist, Department of Natural Resources representatives (or their equivalents) from the states of Minnesota, Illinois, and Iowa, U. S. Army Corps of Engineers representatives from the St. Paul and Rock Island Districts, a commercial clammer, and a representative from the Region 3 Office of the U. S. Fish and Wildlife Service. The objectives of this paper are to briefly review the Recovery Plan and to discuss the problems and the approaches taken while developing it. Some of the unique problems encountered by the team concerning this species will also be discussed.

The Recovery Plan is a document which is divided into four parts. Part 1, the Introduction, is subdivided into four sections. Section 1 is a review of the historical and present distribution of *Lampsilis higginsi*. There is a problem in accurately assessing the historical distribution of this species because of taxonomic problems involving the species group to which *L. higginsi* belongs. However, it is now apparent that *L. higginsi* was found in the Upper Mississippi River from approximately the Twin Cities area south to just above St. Louis and in the lower reaches of some of the major tributaries. It is important to note that while it was widespread, it was not reported to be abundant. The present distribution is much better known as a result of several recent surveys that have been conducted in the Upper Mississippi River (Ecological Analysts 1981, Fuller 1980, Perry 1979, Thiel, Talbot, and Holzer 1979). All of these data indicate that over the last 50 years *L. higginsi* has undergone a 53 percent reduction in its range (Havlik 1981).

Section 2 of the Introduction is a review of what is known ecologically and biologically about *L. higginsi*. Other than a few broad generalizations, there is little available of a specific nature concerning both of these factors.

There are several reasons responsible for the observed decline of *L. higginsi* and these are reviewed in Section 3. Although *L. higginsi*

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was not abundant historically, it was of commercial value and utilized for buttons when obtained by the commercial clamming industry. Fuller (1980) believes that this was partially responsible for its decline. However, the primary factor was probably the significant habitat modifications that have occurred over the last 50 years.

There are some investigators today that question whether *L. higginsi* is an endangered species because of the number of live mussels that have recently been collected. An examination of the endangered species status of *L. higginsi* is reviewed in Section 4. Two terms, "rare" and "endangered," are frequently used interchangeably. While all rare species, because they are not numerically abundant, are endangered, not all endangered species are rare.

Studies conducted around the turn of the century indicated that *L. higginsi* was widely distributed. However, during the 40 years immediately preceding its consideration for endangered species status in 1976, only three individuals were reported collected and no data were available to substantiate the presence of any viable reproductive populations. Evidence indicated that *L. higginsi* was "in imminent danger of extinction" (Red Book 1977). Since its 1976 listing, several major surveys have been conducted in the Upper Mississippi River and live *L. higginsi* have been collected in sometimes surprising numbers. The Recovery Team still believes that *L. higginsi* is endangered, however, because of the 53 percent reduction in its range and because quantitative data are still lacking to verify the presence of viable reproductive populations. Additionally, many of the factors that contributed to its decline are still present.

Part II of the Recovery Plan is a discussion of the objectives and rationale of the plan. The ultimate objective is to delist the species. This can be accomplished (a) by protecting existing viable reproductive populations and their essential habitat and (b) through the enhancement and restoration of the species to suitable habitat throughout its former and present range.

The Recovery Team spent a great deal of time debating and defining the phrases "viable reproductive population" and "essential habitat." While many of the activities proposed in the Recovery Plan are designed to provide qualitative and quantitative data to define these phrases specifically in relation to *L. higginsi*, it is possible to define them on a broader biological basis. The Team avoided using a strictly quantitative approach to define a viable reproductive population because this is difficult, if not impossible, to determine for most species of invertebrates.

A viable reproductive population is one in which recruitment equals or exceeds mortality. Specifically, in relation to *L. higginsi*, it is necessary to be able to verify the following:

a. Viable glochidia (the larval forms in this group that, after

being discharged by the female bivalve, become obligatory parasites on the tissues of a host fish) in the adult female.

b. Presence of the correct host fish(es) at the appropriate time of the year (implicated hosts are the sauger and freshwater drum).

c. Successful establishment of the juvenile bivalves in the substrate.

d. Presence of adults representing several age classes.

A determination of what constitutes suitable habitat involved using historical and present distribution in conjunction with what is known ecologically about *L. higginsi*. Those sites currently supporting *L. higginsi* were assumed to be suitable. Two categories of suitable habitat were recognized. Essential Habitat includes those localities where there is some evidence of reproduction, i.e. those habitats with populations that represent the best chances of survival for the species. The remaining sites are designated as Other Suitable Habitat and include those localities that currently support *L. higginsi*, but only marginally, and represent areas that might be suitable for future transplants. One factor that is valuable in determining the latter is species diversity. Numerous investigators have demonstrated that riverine habitats, similar to those occupied by *L. higginsi* in the Upper Mississippi River, are characterized by a high species diversity, while lentic habitats have a low species diversity. Nelson and Freitag (1980) have noted that *L. higginsi* was associated in at least 50 percent of the collections with 17 common or wide-ranging naiad species. Therefore, the nature of the associated fauna is partially indicative of the suitability of the habitat.

The U. S. Fish and Wildlife Service requires that the Recovery Plan specify what criteria must be met to determine the point at which *L. higginsi* is to be considered recovered. The Recovery Team has used a multiple criteria approach rather than a single quantitative value simply indicating some fixed number of males and females. The first criterion is the establishment of a minimum of five viable reproductive populations to include the Prairie du Chien population. These populations should be studied to obtain qualitative and quantitative data and the populations should be monitored for a minimum of 10 years to verify the stability of the population. Secondly, to minimize the impact of any detrimental activity at a particular site, for the protection of the species as a whole, viable reproductive populations should be maintained in five separate Upper Mississippi River pools to assure a range sufficient for the security of the species. If these criteria are met, the Recovery Team would meet to discuss a recommendation to upgrade the status to Threatened.

The remainder of Part II consists of an outline and accompanying narrative discussing those actions necessary to achieve the stated

objective. There are a variety of proposed activities, including basic research (involving such items as reproductive biology, habitat requirements, and restoration and transplanting techniques), various regulatory measures, establishment of monitoring programs, and public education.

Part III of the Recovery Plan considers costs necessary to accomplish the various objectives, indicates agencies responsible for each activity, and establishes a priority for each action.

The last major section of the Recovery Plan (Part IV) is a discussion of specific sites that are proposed for designation as Essential (=Critical) Habitat. There were special problems that had to be considered when trying to designate Essential Habitat in lotic environments. Terrestrial habitats and their associated fauna are frequently more easily protected for several reasons:

a. Some sites are isolated geographically.

b. The organisms themselves may be highly visible, facilitating the identification of their range.

c. Some sites are easily protected by using simple physical barriers.

By contrast, in riverine environments it is difficult to prevent detrimental activities upstream from having a deleterious effect on the bivalve fauna. Additionally, the animals are not easily located, and much of the range of *L. higginsi* is still subject to impacts that will not or cannot be eliminated.

The Higgins' Eye Mussel Recovery Team utilized several criteria to evaluate each potential site. Only those sites presently occupied by live *L. higginsi* were considered. While the numerical abundance at each locality was noted, the Team felt that this factor alone was not enough to confer Essential Habitat status on a particular site. Historical and present distributional data in the literature were utilized, as well as verifiable museum and personal records. Consideration was given to the number of investigators that independently found specimens in proximity to each other. When available, additional data examined included: the presence of both male and female bivalves at a given locality; the presence of gravid females; individuals representing several age classes; and species diversity.

Of the approximately 17 localities initially considered, sufficient data were available to designate 7 sites as Essential Habitat. Certainly the remaining sites should be the focus for some of the initial studies proposed in the Recovery Plan.

The remainder of the Recovery Plan document consists of several appendixes, one of the most important of which is a discussion of relocation recommendations. "Relocation" is defined as the transplanting of

individuals or populations of *L. higginsi* that are in imminent danger of destruction. The Team does not endorse the relocation of mussels as a general approach, but rather only as a final alternative.

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Discussion

J. Peach: You said that the commercial clamming industry was responsible for a decrease in the numbers of the Higgins' Eye mussel. On what information do you base this statement?

E. Stern: That was based on information in the literature, not personal observations. I can give you the citation for that.

J. Peach: Was the fact that Higgins' Eye was found in the Muscatine (Iowa) area, where there was a lot of button acitvity, responsible for this?

B. Whiting: Yes. We have also found Higgins' Eye in the shell piles at Prairie du Chien, and have encountered professional clammers who had taken *Lampsilis higginsi*. I do not think that Ed Stern meant that professional clamming was the only reason for the decline of Higgins' Eye. This was probably one of several factors.

J. Peach: Muscatine was once the button capitol of the world. Shells were brought in from all over the country, even as far away as the Rio Grande. It may be an invalid assumption to suggest that commercial clammers in the Upper Mississippi River took all those Higgins' Eyes.

E. Stern: I did not mean to imply that professional clamming was the primary factor. Certainly other things were responsible for the decline of *L. higginsi*.

INVOLVEMENT OF THE U. S. ARMY ENGINEER DISTRICT, ST. PAUL, WITH FRESHWATER MOLLUSKS

by

Robert J. Whiting*

Introduction

Of the 860 miles of navigable river channel in the Upper Mississippi River maintained by the Corps of Engineers, the St. Paul District is responsible for the 242.5-mile stretch from Minneapolis-St. Paul to Guttenberg, Iowa (Figure 1). The Rock Island and St. Louis Districts are responsible for the remainder of the Upper Mississippi. The St. Paul District also maintains 14.7 miles of congressionally authorized 9-ft channel in the Minnesota River and 24.5 miles in the St. Croix River, both of which flow into the Mississippi.

The predominant sediment type in the St. Paul District portion of the Upper Mississippi is sand. The District dredges an average annual volume of approximately 1.4 million cu yd from the navigation channel with three dredges: a 20-in. hydraulic pipeline dredge, the WILLIAM A. THOMPSON; a 12-in. hydraulic pipeline dredge, the DUBUQUE; and a 4-cu-yd clamshell dredge, the HAUSER. The two hydraulic dredges pump dredged material through floating pipelines, usually to an on-land disposal site. The clamshell dredge loads into barges and usually directly unloads from the barges into an on-land disposal site.

No federally listed threatened mollusks are known in the St. Paul District. Two species of federally listed endangered freshwater mussels, however, have been recorded from the Mississippi River in the St. Paul District: the fat pocketbook (*Proptera capax*) and the Higgins' eye pearly mussel (*Lampsilis higginsi*), both officially listed as endangered species on 14 June 1976. Living or dead specimens of *Proptera capax* have not been collected from the St. Paul District since the Ellis survey, almost 50 years ago. Fuller (1980) concludes that the species is probably now extirpated from the St. Paul District. A number of recent investigators have demonstrated that *Lampsilis higginsi* is present in the St. Paul District. Havlik (1981) has shown that present distribution of the species in the Upper Mississippi River only includes about one-half of its historical range.

Two main centers of distribution of *L. higginsi* lie within the District: one on the St. Croix River near Hudson, Wisconsin, and another in navigation Pools 9 and 10 which include several sites, the best known being the east channel at Prairie du Chien, Wisconsin, in Pool 10.

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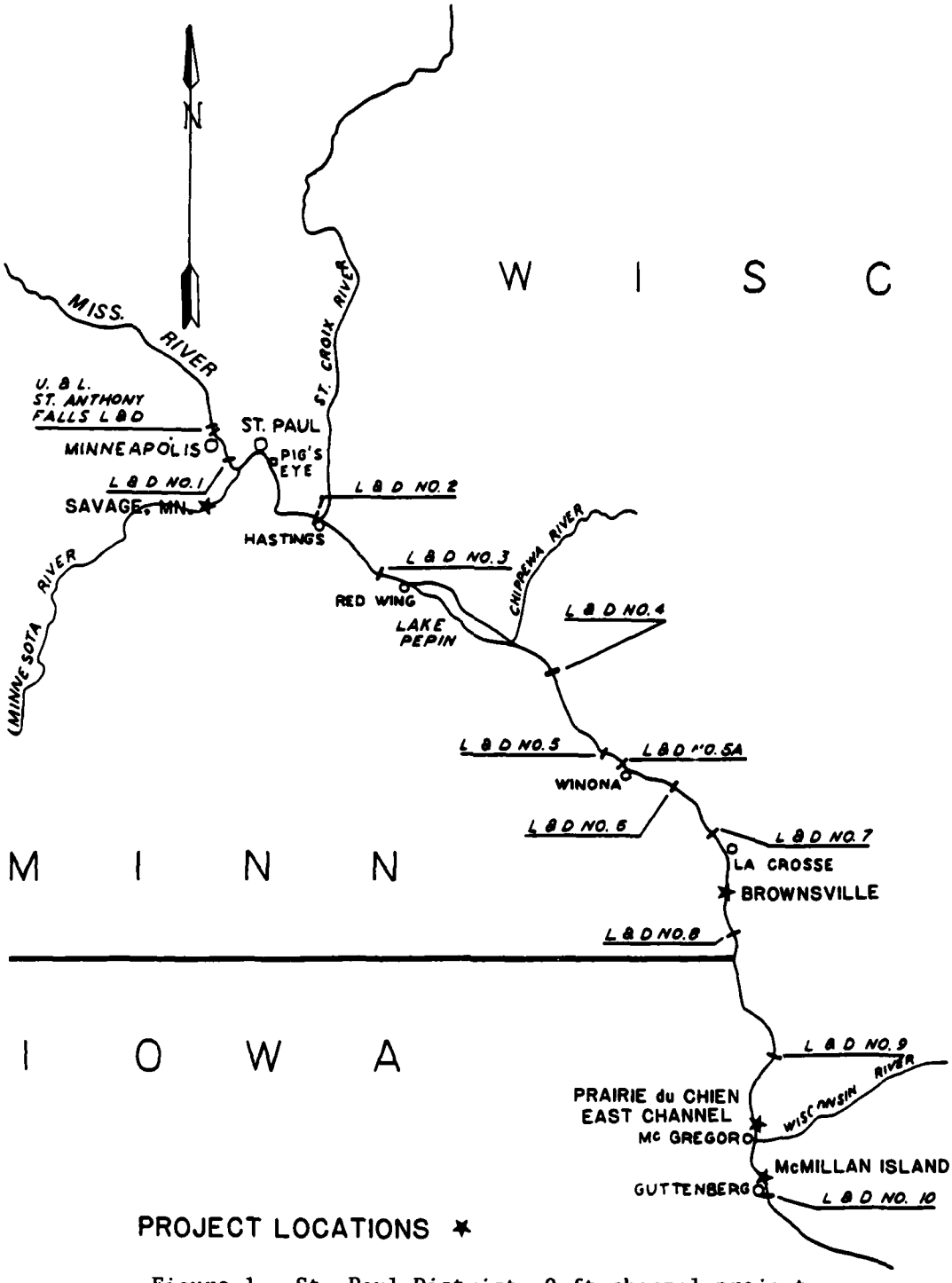

Figure 1. St. Paul District, 9-ft channel project

Approximately 150 living *L. higginsi* have been collected since 1968. Most of these were found by the Wisconsin Department of Natural Resources; the St. Paul District, Corps of Engineers; and Marian Havlik of Malacological Consultants. Because of limited quantitative data, a statistical estimate of population size has never been attempted.

Endangered Species Section 7 Consultation

In fall 1976, the St. Paul District initiated a formal Section 7 consultation with Region 3 of the U. S. Fish and Wildlife Service (FWS). The first step in this consultation procedure was a formal threshold examination to determine if the proposed action (operation and maintenance of the 9-ft navigation channel) was impacting the endangered Higgins' eye pearly mussel. The conclusion of the threshold examination was that "maintenance dredging on the Upper Mississippi River may jeopardize the continued existence of the species and/or adversely modify the habitat which may be determined to be critical to the species." Sufficient information did not exist at the time to determine critical habitat. In order to make a biological opinion on whether maintenance dredging modifies critical habitat, it would be necessary to determine the location and extent of existing clambeds. Further, in order to make a judgment whether maintenance dredging would jeopardize the continued existence of the species, it would be necessary "to determine the effects of siltation on mollusks and the effectiveness of turbidity screens and/or polymer sedimentation."

As a result of the threshold meeting, the St. Paul District undertook three actions: (1) the District contracted the Academy of Natural Sciences of Philadelphia to conduct mussel surveys at potential dredging sites on the Mississippi River (see Fuller 1978, 1980); (2) the District contracted with the FWS Fish Control Laboratory in LaCrosse, Wisconsin, to conduct bioassays on effects of sedimentation on mussels (see Marking and Terry, 1977); and (3) the District prepared a contingency plan for initial actions that would be taken should an endangered mussel be located in an area proposed for maintenance dredging.

Throughout the development of all of these actions, the District encouraged active participation by the FWS and State natural resource agencies and held several coordination meetings with these agencies.

The mussel surveys headed by Mr. Samuel Fuller of the Academy of Natural Sciences of Philadelphia began in July 1977 and concluded in September 1979. The findings of the study are included in two reports by Fuller (1978*, 1980). As part of the contract requirements, the Academy of Natural Sciences also developed a mussel poster which portrayed the mussels of the Upper Mississippi.

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* The St. Paul District, Corps of Engineers, jointly funded the first year of the study with the Rock Island District.

The District's efforts in carrying out the Section 7 consultation were given considerable recognition and commendation by the FWS and the Corps of Engineers. On 10 April 1978, Mr. Jack Hemphill, Regional Director for the FWS sent a letter to the North Central Division Engineer, Colonel Remson, commending the St. Paul District's efforts in conducting the study and carrying out the consultation process. Mr. Hemphill stated that it represented an "outstanding example of how Section 7 consultations should be handled." Further, the Service stated that it intended to use the consultation as an example of how the act is to be administered. As a result, the Service obtained Colonel Remson's permission to write an account of the effort and present it as a feature article in the widely distributed Endangered Species Bulletin (see Inclosure 1).

St. Paul District Encounters with Endangered Mussels

Even though the St. Paul District, Corps of Engineers, and Region 3 of the FWS expended a great deal of effort in the Section 7 consultation process, the endangered mussel *Lampsilis higginsi* was encountered in at least three, and possibly four, instances during maintenance dredging on the Upper Mississippi River. The following narrative discusses these four instances. In each case, the events leading to the encounter are described, followed by a discussion of what happened as a result of the encounter.

Mississippi River - East Channel, Prairie du Chien, Wisconsin, August 1976

On 2 April 1976, the District issued the "1976 Navigation Season Public Notice of Channel Maintenance," which included maintenance dredging at the southern end of the east channel. Public hearings were conducted at St. Paul and Winona, Minnesota, and at Prairie du Chien, Wisconsin, to receive comments on the public notice. Dredging was proposed for the east channel (Figure 2) because adequate depth was no longer available for safe access to the city's commercial harbor for 9-ft draft vessels except during high water periods.

On 18 May 1976, representatives of the District met with the Prairie du Chien City Council, local commercial clammers, representatives of the State of Wisconsin, the Wisconsin Department of Natural Resources, the U. S. Fish and Wildlife Service, and members of the Great River Environmental Action Team (GREAT). This coordination effort revealed that there was a very strong interest in maintaining an access to the commercial harbor and that there was a beneficial use of the dredged material. However, there were also concerns over possible damage to the commercially harvestable mussel beds and to possible adverse effects on the endangered Higgins' eye pearly mussel. As a result of this coordination, the dredging project was modified to avoid the significant mussel beds in the southern portion of the east channel. Instead, the dredging

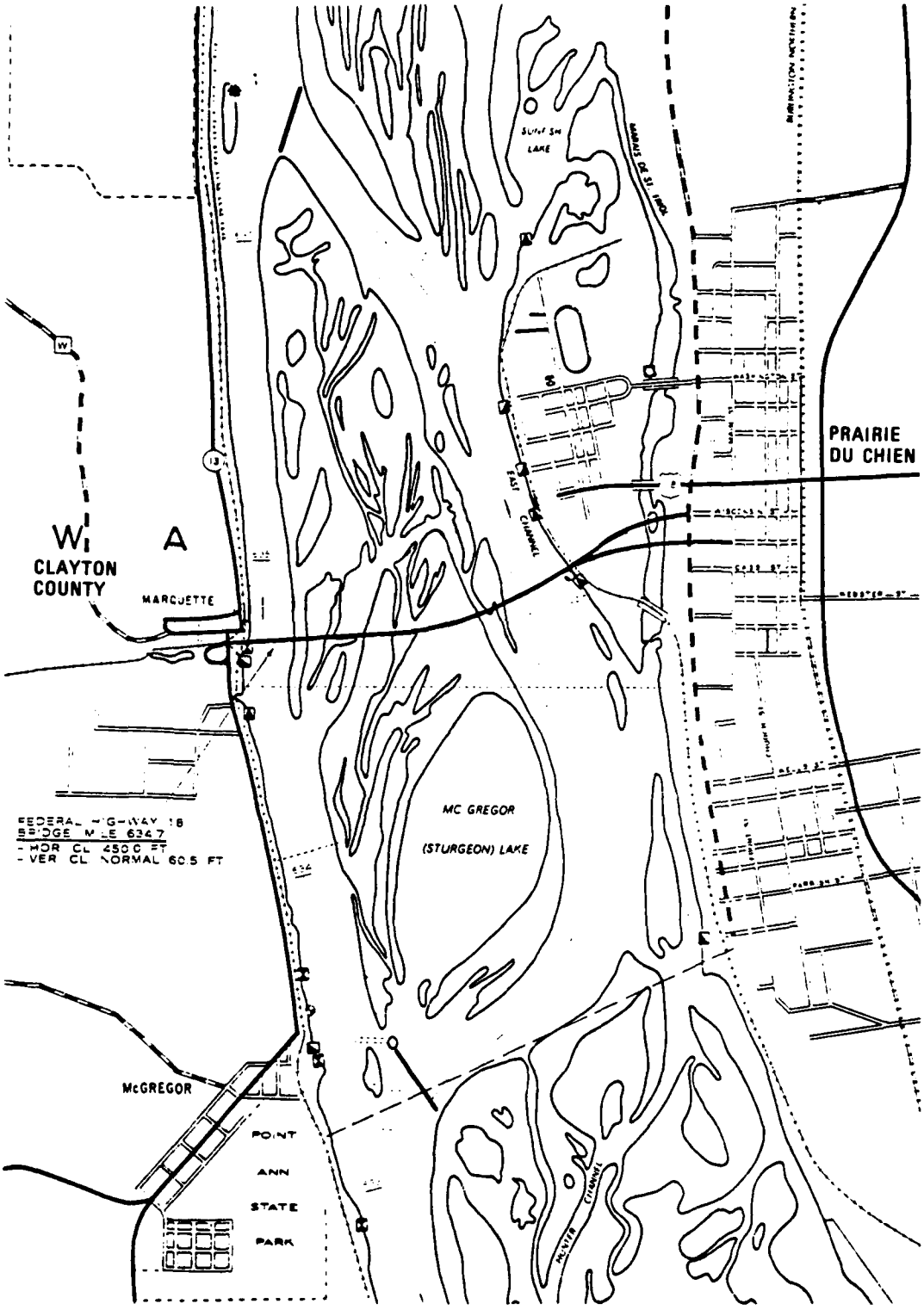

Figure 2. East Channel at Prairie du Chien

was proposed for the northern entrance where the commercial clammers indicated that they had not encountered mussels in recent years (Figure 3). The proposal to dredge the northern entrance required use of the 20-in. hydraulic pipeline dredge, the WILLIAM A. THOMPSON, and double pumping of 65,000 cu yd of dredged material to reach the selected beneficial use site above the interstate bridge.

In a 7 July 1976 letter, Ms. Marian Havlik, a local malacologist, indicated her concern that the proposed dredging would adversely impact *L. higginsi* in the east channel. Ms. Havlik was invited to attend an on-site meeting scheduled for 22 July 1976.

On 14 June 1976, *L. higginsi* was officially listed as an endangered species in the Federal Register.

The scheduled on-site meeting was held at Prairie du Chien on 22 July 1976, and was attended by local commercial clammers, interested citizens of the city of Prairie du Chien and the States of Iowa and Wisconsin, personnel of FWS, and members of the Great River Environmental Action Team. The revised dredging plan was presented and was accepted by all attendees.

Dredging commenced on 23 July 1976 and ended on 10 August 1976. Following the dredging, Ms. Havlik investigated the dredged material at Prairie du Chien and reported finding several recently dead shells of *L. higginsi* among several thousand specimens of nonendangered species (Havlik and Marking 1980).

On 23 November 1976, the FWS responded by letter to an inquiry from Senator Dick Clark on behalf of Ms. Havlik. Ms. Havlik had charged that the U. S. Army Corps of Engineers had knowingly violated the Endangered Species Act of 1973 by dredging in the east channel at Prairie du Chien, Wisconsin. The conclusion of the FWS letter indicated the following:

> ...It is our belief that reasonable precautions were taken by the U. S. Army Corps of Engineers and others involved to assure that their dredging operations would not jeopardize this endangered species. In addition critical habitat for *L. higginsi* was not determined at the time the species was listed as endangered, nor has any critical habitat been proposed for it to date...

Minnesota River,
Savage, Minnesota, March 1977

On 22 March 1977, hydraulic dredging operations on the Minnesota River resumed under a private contract (Figure 4). The dredging had originally started in the fall of 1976 but cold weather had prohibited project completion at that time. The material placement site was on the

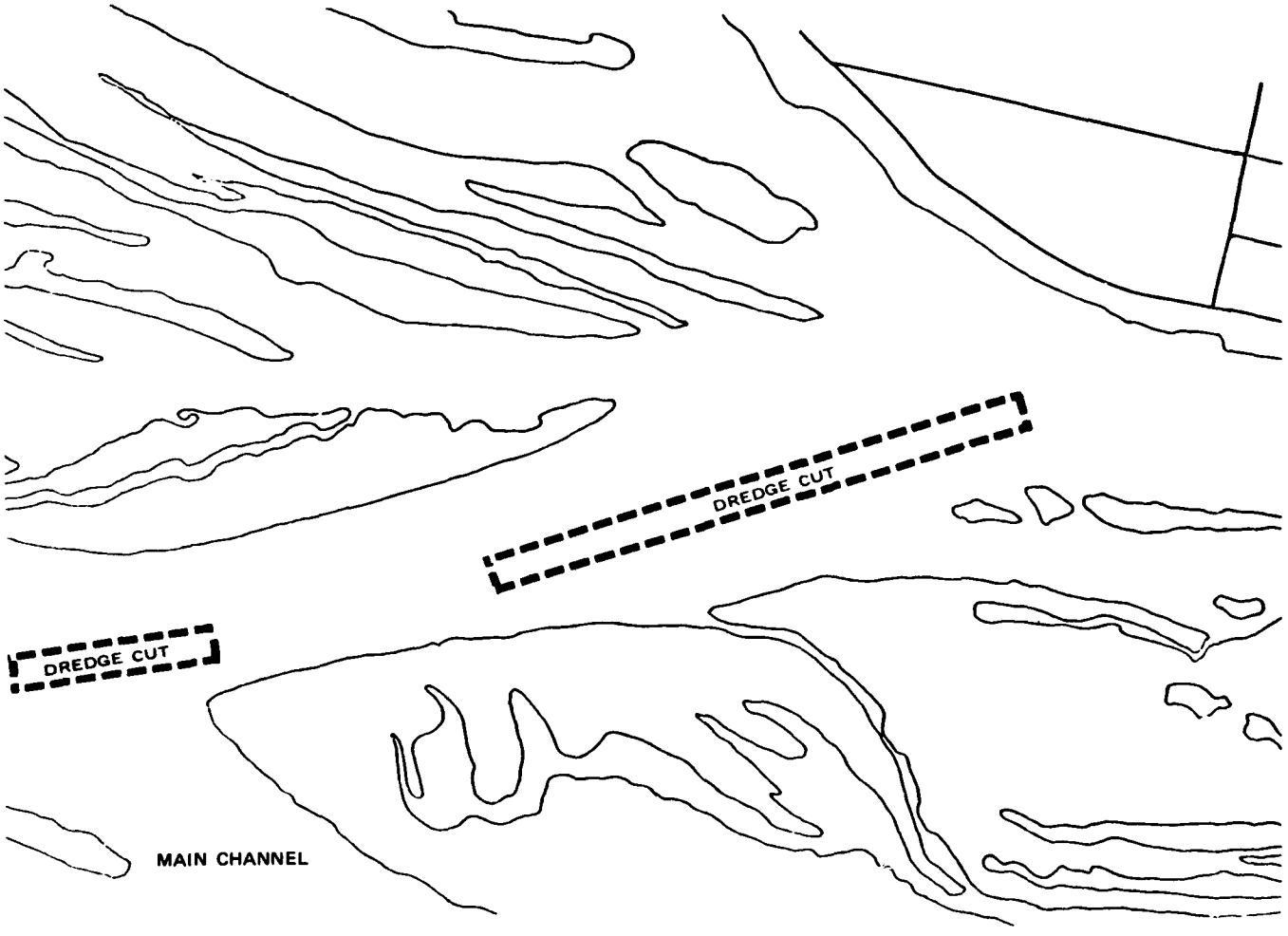

Figure 3. August 1976 dredging, Prairie du Chien east channel

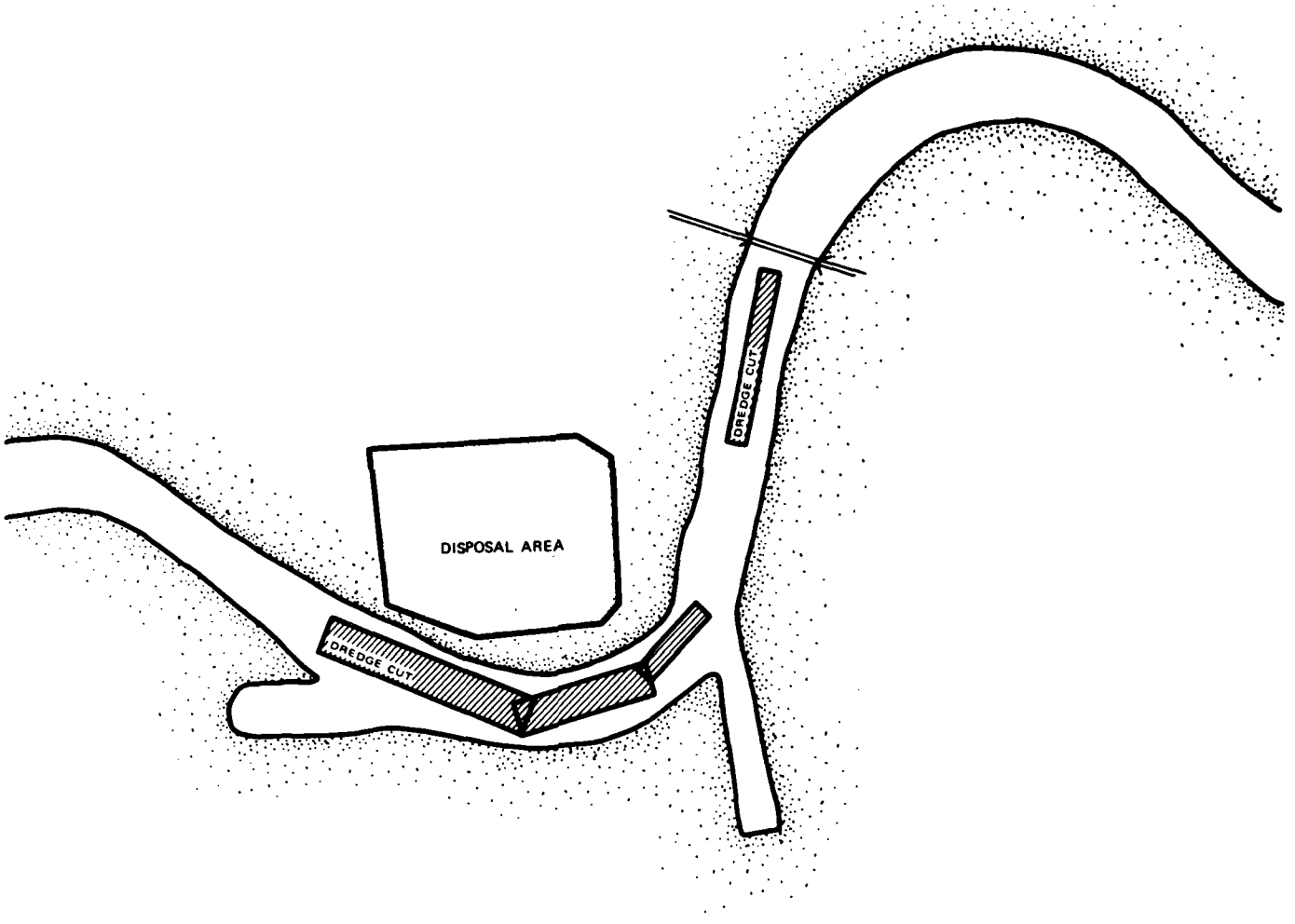

Figure 4. March 1977 dredging, Savage, Minn., river mile 14.6

left descending bank above the Savage Railroad Bridge. Site selection was fully coordinated with GREAT, Federal, State, and local agencies. Due to the poor water quality conditions of this section of the Minnesota River, it was believed that mussels could not exist there, so a survey was not done.

On 23 March 1977, an inspection of the placement site by Corps of Engineers Biologists, prior to the initiation of dredging, revealed several species of clams, including part of one specimen believed to be the endangered *L. higginsi* species. Dredging operations were halted until a comprehensive investigation of the dredge site could be accomplished. Dr. David Stansbery, a malacologist at Ohio State University and Ms. Havlik were contracted to perform on-site species identification.

Cold water and high current velocities made brailing impractical. An attempt to conduct the survey with Corps of Engineers divers failed after they encountered strong currents. Since the other methods of sampling failed, the cranebarge WADE, a 3-cu-yd clamshell, took 10 samples throughout the dredge cut. Each sample was placed on a flat-bottomed barge and washed with a hose in such a way as to leave all shell material, rocks, etc., on the deck of the barge.

All sampling efforts produced no living mussels of any species. Hydraulic dredging of a test section was then initiated and an inspection of the placement site was conducted in conjunction with the dredging. This effort also did not produce any living mussels. Several other test dredging sections were completed until it was established that the dredging site did not contain living mussels. Full dredging operations were resumed on 25 March 1977.

The valve suspected of being a male *L. higginsi* was not confirmed as such by Dr. Stansbery who indicated that there was simply not enough information in the single valve to distinguish between a male *L. higginsi* or a male *Actinonaias carinata*. The valve is now catalogued at the Ohio State University Museum as an "unidentified mollusk."

Mississippi River,
Brownsville, Minnesota, August 1977

Hydrographic surveys conducted at Brownsville on 6 and 7 July 1977 disclosed that channel maintenance dredging was necessary at this location. An on-site inspection meeting was held on 9 August 1977 at Wild Cat Landing Park in Brownsville. Representatives of local, city, county, State, Federal, and GREAT interests were in attendance.

Dredging at this site was scheduled to be accomplished with the Dredge WILLIAM A. THOMPSON as it proceeded en route to the Rock Island District. Three proposed placement sites were carefully reviewed by the on-site inspection team. All three were on the right descending bank, below the dredge cut and within the Brownsville city limits. The site finally selected was below the existing marina and consisted of former

dredged material composed of medium-fine sand, sparsely vegetated with willows. The proposal was to place the material between the high point of previous dredged material and the railroad embankment (Figure 5). This area was directly above a wetland and, therefore, it was decided to construct a berm on the upper end of this wetland to prevent any encroachment of material into the wetland. Construction of the berm required advanced preparation of the disposal site prior to dredging. Advanced site preparations were initiated on 12 August 1977 and completed on 15 August 1977.

Under a previous agreement with the FWS as part of the Section 7 consultation procedure, the St. Paul District was required to survey for endangered mussels prior to any dredging. The Academy of Natural Sciences of Philadelphia, under contract with the Corps, surveyed the Brownsville site on 14-15 August 1977. The surveying technique used was brailing. A total of 157 mussels, constituting 11 species, were collected during the survey. *L. higginsi* was not among the species found during the survey. The FWS was notified of the survey results.

Dredging was initiated on 17 August 1977 and completed on 19 August 1977; 24,000 cu yd of material was dredged. After the dredging, a recently deceased mussel ultimately identified as a juvenile *L. higginsi* was discovered on a fresh disposal bank. After the FWS was notified of this situation, they concluded that the Corps of Engineers had complied with Section 7 of the Endangered Species Act.

Mississippi River,
McMillan Island, October 1980

McMillan Island is in Clayton County, Iowa, near Cairo at about mile 617.6 in Pool 10 of the Upper Mississippi River (Figure 6). Guttenberg, Iowa, and Lock and Dam 10 are about 2 miles downstream of this site.

Based on historic records of maintenance, the dredge site at McMillan Island has a dredging frequency of 17 percent, requiring maintenance dredging approximately 2 out of every 10 years. The average volume dredged per event at this site is 41,000 cu yd. Prior to the dredging discussed in this paper, the site had last been dredged in 1973. The area of the dredge cuts is on the right side of the channel, beginning at about mile 617.6 and extending to about mile 618.5.

The McMillan Island dredge cuts were proposed for dredging in the fall of 1979. An On-Site Inspection Team (OSIT) meeting was held in Guttenberg, Iowa, on 25 September 1979 to discuss the proposed dredging. Representatives of the St. Paul District, the FWS, the Iowa Conservation Commission, and the U. S. Coast Guard attended. A method for dredging and disposal was agreed upon by the agencies at this meeting. Under the agreed-upon method, the means to accomplish the removal of accumulated sediment would necessitate double handling techniques. Two temporary rehandling sites were considered. Site 1 was located off the main

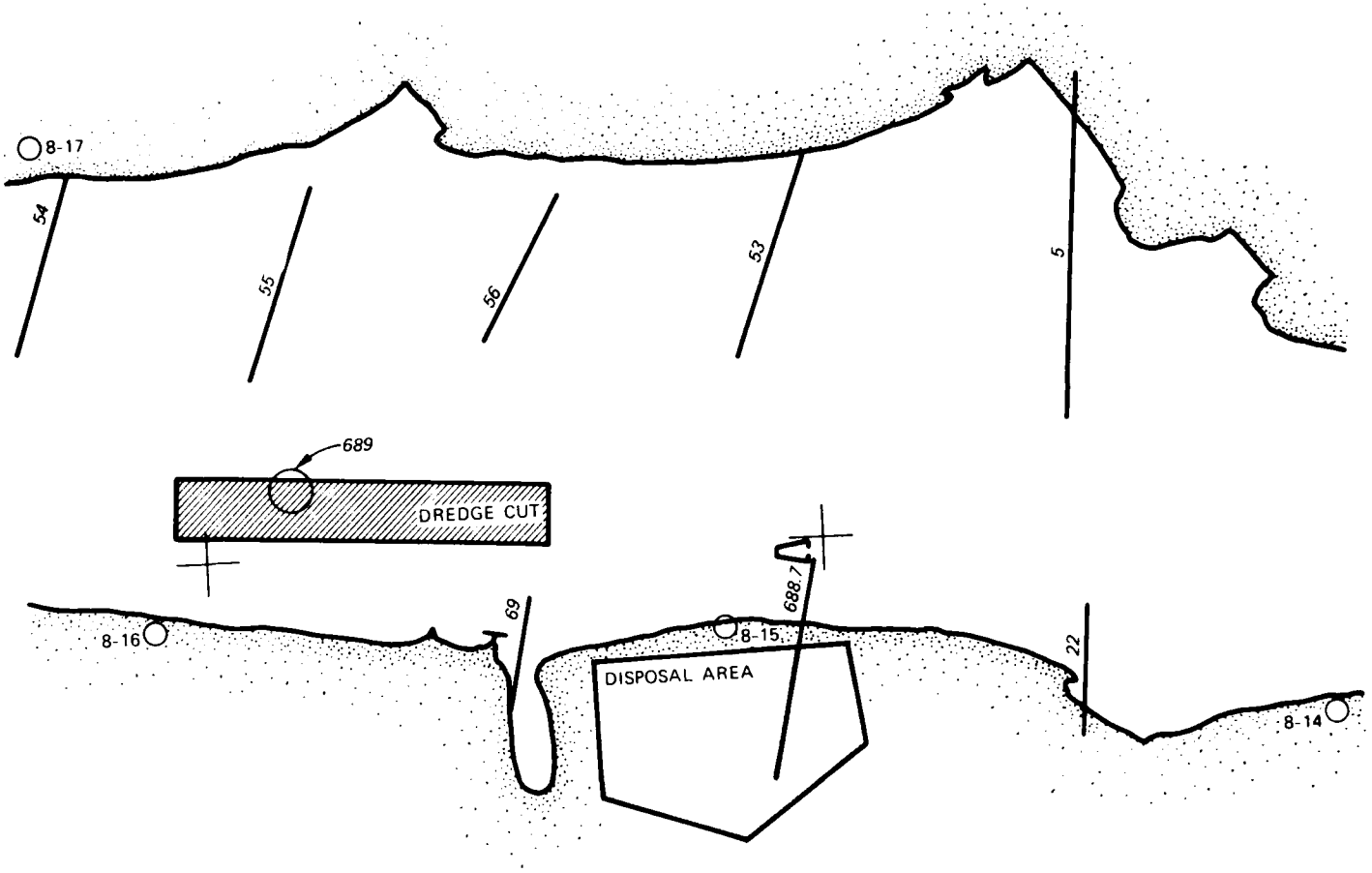

Figure 5. August 1977 dredging, Brownsville, Minn.

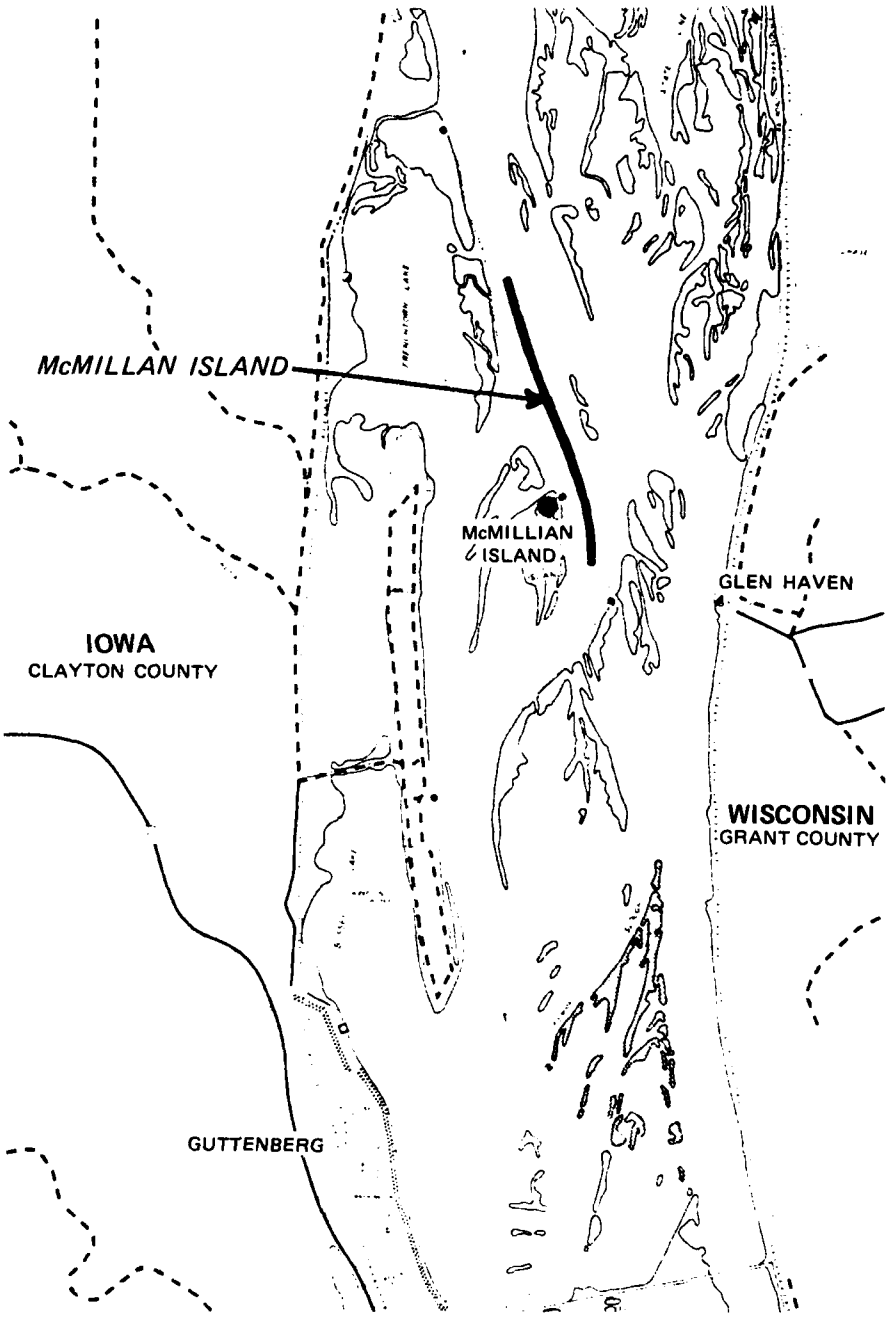

Figure 6. McMillan Island

channel on the right bank at about mile 617.5. The area was characterized by a hard sandy bottom, moderate current, and depths ranging from 1 to 10 ft. Site 2 was located off the upriver end of McMillan Island, off the right side of the main channel at about mile 619. The area was characterized by a moderate current over a sandy bottom. The area was very shallow, dropping to greater depths close to the main channel. Site 1 was agreed upon at the OSIT meeting as the rehandling site, with site 2 serving as an alternate rehandling site. From the rehandling site, material would then be pumped to a gravel pit on Abel Island for disposal.

While no objection to this dredging alternative was raised at the OSIT meeting, there was some doubt expressed about the need and justification for late-season dredging. Members of the OSIT could foresee no benefit for the 1979 navigation year from late-season dredging. Further, the OSIT members believed that the normally high bed load and high 1980 spring flows would negate any benefits derived from the late 1979 dredging. Ultimately, due to this controversy and the unavailability of equipment, dredging at McMillan Island was postponed pending further observation in 1980.

Hydrographic surveys taken at McMillan Island on 13 May 1980 indicated that dredging would be required to maintain a recommended navigation channel width of 500 ft. Based on this information, dredging was rescheduled for 1980.

The dredging and disposal method proposed in 1979 was then readopted for 1980. Since in-water disposal was to be used, the St. Paul District considered possible environmental impacts that could occur. Several events alerted the St. Paul District to the possible presence of the endangered mussel *L. higginsi* near McMillan Island. The Wisconsin Department of Natural Resources (WDNR) had discovered several live specimens of *L. higginsi* in Pool 10; specifically, from the Prairie du Chien, Wisconsin area (Figure 7). Additionally, Mr. Samuel Fuller of the Academy of Natural Sciences of Philadelphia, in a survey conducted for the St. Paul District, found *L. higginsi* in the Prairie du Chien area. Mr. Fuller did not locate any endangered mussels in the Guttenberg area, but he did find a large and diverse mussel community near McMillan Island. Figure 8 shows the area sampled by Fuller in 1979.

In order to more fully assess the status of *L. higginsi* in the McMillan Island area, Corps of Engineers personnel conducted additional mussel surveys on 5 August 1980 and 17 September 1980. Brailing was the only method of collection employed for these surveys. Figure 8 shows the areas sampled in August and September. Tables 1 and 2 contain the results of these surveys. On transect 3 at the lower end of McMillan Island in the 5 August survey, one live specimen of *L. higginsi* was found. The specimen was transported to the FWS National Fisheries Research Laboratory in La Crosse, Wisconsin, where it was held until its identity could be confirmed and arrangements could be made to replace it in a viable condition at its point of capture. Because an endangered

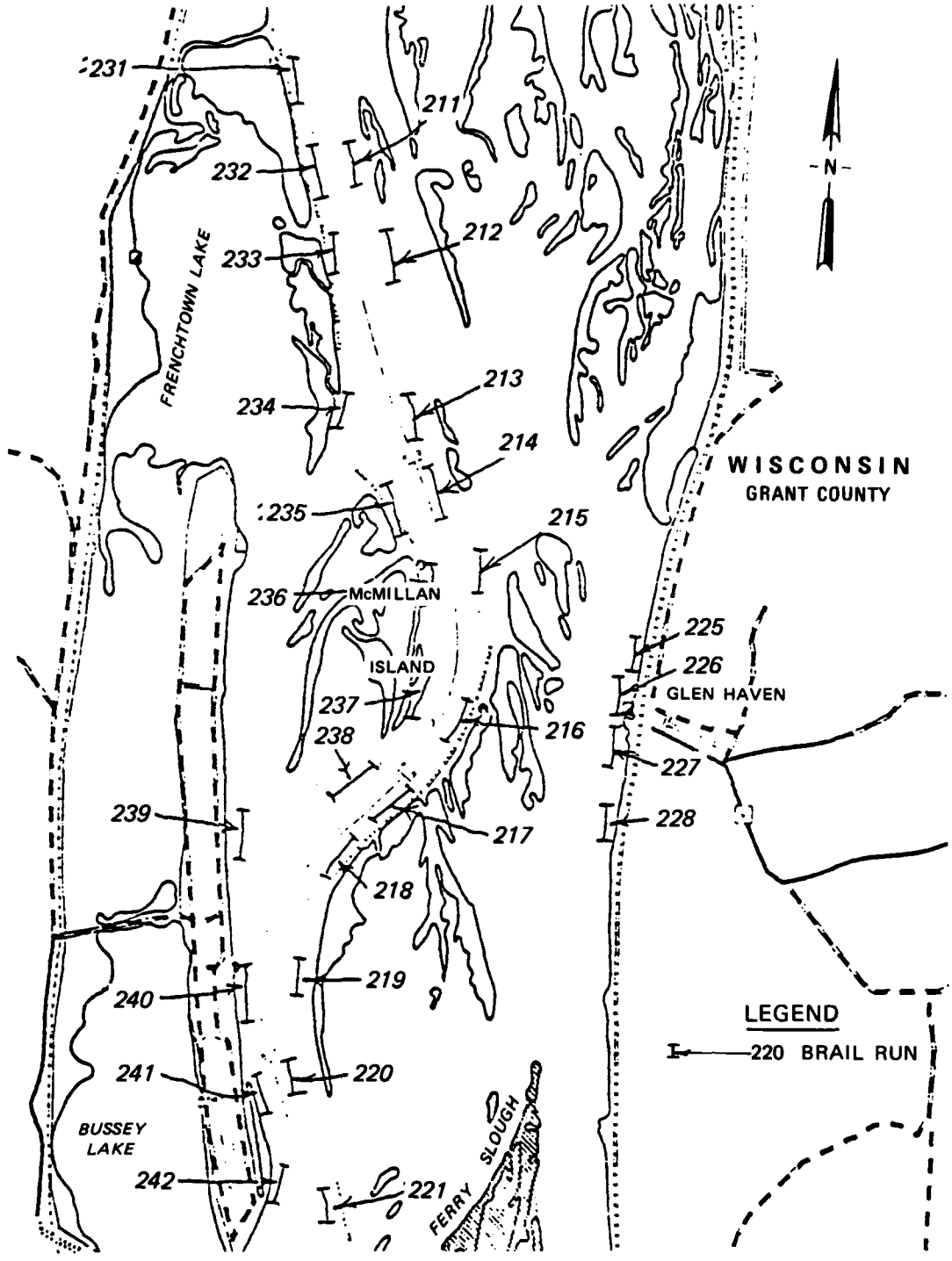

Figure 7. Locations of brail runs from Wisconsin Department of Natural Resources, 1979 Mussel Surveys

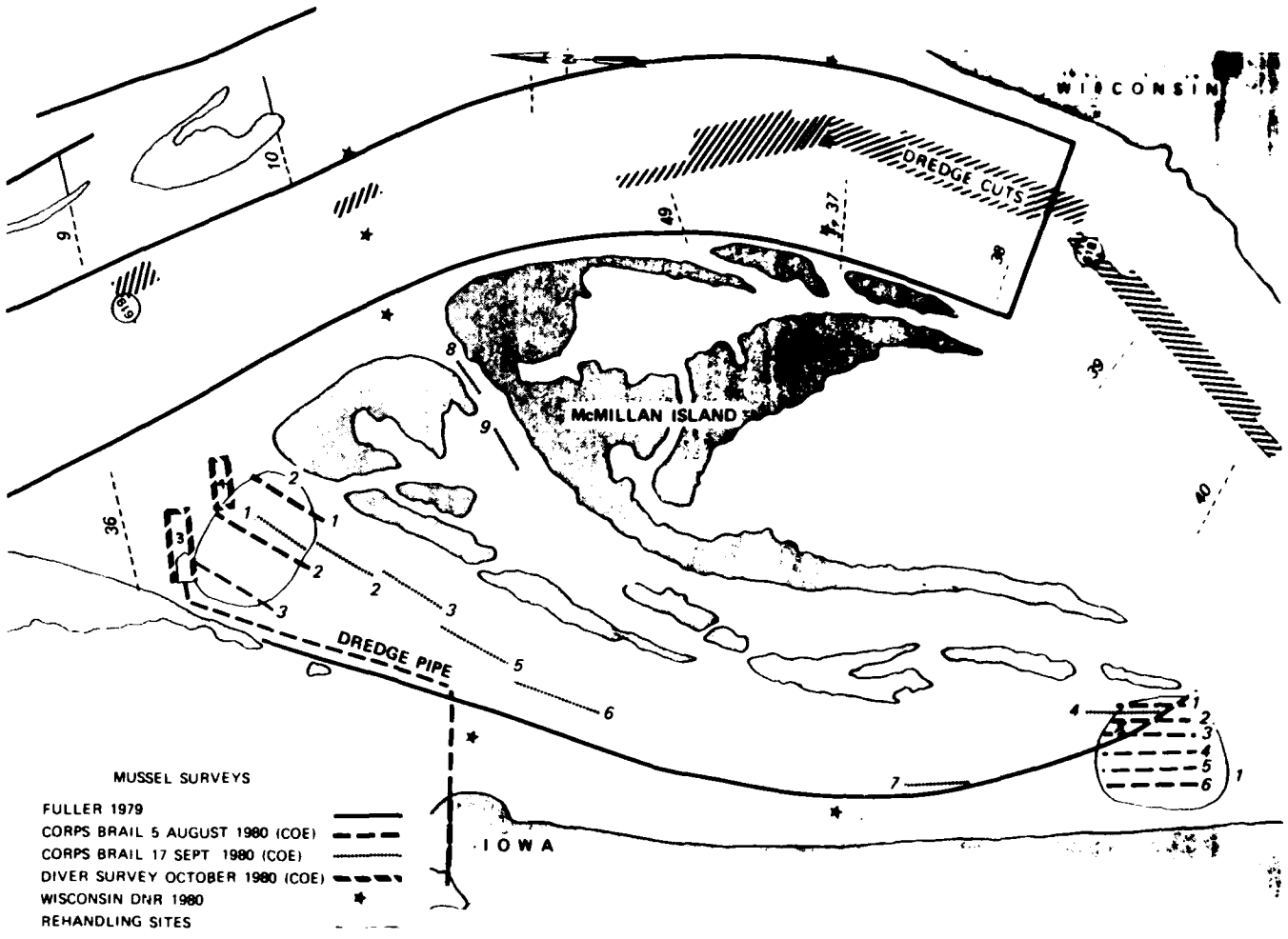

Figure 8. McMillan Island dredging surveys

mussel was found in the primary rehandling site, the site was environmentally unacceptable for that use. Additionally, in early September 1980, the WDNR conducted mussel surveys in the McMillan Island area and found *L. higginsi* at about mile 617 (see Figure 8 and Tables 1 and 2). The Corps of Engineers received word of this find on 19 September 1980.

The alternative rehandling site (site 2, Figure 8) was also surveyed, on 5 August and 17 September 1980. The results of the surveys indicated an impoverished mussel community in the area. Therefore, it was recommended that the proposed dredging operation proceed using site 2. No objection was raised to this recommendation at this time. It became evident that the dredging plan to be used would be difficult to implement in this alternative site. The site was generally too shallow to accommodate the bottom-dump barges during unloading. Also, some parts of the rehandling area were too far from the on-land disposal site to be reached with the available equipment.

When dredging was to commence, an area of 100 by 400 ft was to be marked by buoys as the rehandling site. The boundaries of the approved rehandling site were apparently misunderstood. The area marked off for rehandling was inadvertently relocated just outside the approved boundaries, slightly upstream (site 3 on Figure 8). In order to accommodate the bottom-dump barges, an area 100 by 100 ft within the marked area was dredged to 11 ft by the DUBUQUE.

Corps of Engineers personnel were conducting water quality monitoring studies on 22-23 October 1980 at the dredge site. During an equipment breakdown of the dredge, an inspection of the gravel pit disposal site revealed the presence of many mussels in the dredged material, including two specimens believed to be *L. higginsi*. It was concluded that these specimens came from the rehandling site. Both specimens were dead as a result of being displaced by the dredge. Most specimens found were dead from damage or displacement. Some live mussels were found, however, and returned to the water. Undoubtedly, more specimens were buried in the dredged material.

The two dead specimens believed to be *L. higginsi* were transported to the District offices in St. Paul. On 24 October 1980, it was confirmed that these two specimens were indeed the endangered *L. higginsi*. At this point the dredge DUBUQUE suspended all dredging activity.

On the afternoon of 24 October, Mr. Merle Bailey, FWS, was informed of the events leading up to the discovery of *L. higginsi* at the dredge site. Mr. Bailey was also informed that some dredged material had been deposited in the rehandling area beyond the 100- by 100-ft area dredged to 11 ft.

Mr. Bailey approved a request of the St. Paul District to remove this overburden, dredging to near the original bottom in an attempt to recover living (if possible) specimens of *L. higginsi* that may have been buried. The DUBUQUE then removed this material to within 6 to 12 in.

from the original bottom. The dredge was idle over the weekend of 25-26 October 1980.

The Corps of Engineers diving crew began conducting extensive mussel surveys in and around the rehandling area on 27 October 1980. On the morning of 28 October the divers brought up six live specimens of *L. higginsi*. Of these six specimens, two were found within the rehandling area (site 3, Figure 8) and four were found outside the perimeter of the area. (Tables 3 and 4 contain the results of the diver surveys.) The presence of *L. higginsi* in the rehandling area rendered the site environmentally unacceptable for that use.

Representatives of the St. Paul District and Region III FWS discussed relocating the rehandling site to an area that the dredge could reach near the upriver end of McMillan Island (site 4, Figure 8). Representatives agreed to the use of that site, provided that it could be shown that no *L. higginsi* were present in the area. The diving crew was directed to survey a new area buoyed off at the end of McMillan Island. Here the divers found five specimens of *L. higginsi* (four living and one dead), making this area also unacceptable as a rehandling site.

At this point a limited dredging program was discussed. In order to widen the channel for safe navigation, approximately 4000 cu yd still required removal. It was decided to:

a. Remove the overburden from the entire rehandling area to near the original bottom contour.

b. Dredge the critical areas in the McMillan Island cuts to allow adequate channel width for safe passage.

c. Deposit this dredged material in only the 100- by 100-ft area that had been previously dredged to 11 ft for rehandling.

d. Rehandle all dredged material from this area to the gravel pit for disposal.

On 28 October, late in the afternoon, the St. Paul District instructed the dredging crews to proceed according to this program.

All live specimens of *L. higginsi* collected by the Corps of Engineers were returned to the water in a viable condition. All specimens were returned to the lower end of McMillan Island (see X in site 1 in Figure 8). The single specimen collected in August was placed in this area, by hand, by divers from the WDNR. All specimens collected by Corps of Engineers divers on 28 October 1980 were placed in this area, by hand, the same day they were collected. Each specimen was replaced individually into the substrate, in the proper position, to ensure its survival.

By removing accumulated material from critical areas of the dredge

cuts, adequate widths for navigation have been obtained for the balance of the 1980 navigation season. Present channel width is only 425 ft in some sections of the McMillan Island cut, which is less than the recommended width of 500 ft. Channel width is a critical factor to navigation in this stretch of the river since the river makes a number of fairly sharp turns here. The Corps of Engineers anticipates the need to conduct additional maintenance dredging in this area during 1981 in order to obtain recommended channel widths. When additional dredging is proposed, all feasible dredging and disposal alternatives will be reviewed in order to avoid the recurrence of any impacts on endangered mussels, as well as other environmental impacts.

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Discussion

E. Stern: How was the situation resolved?

B. Whiting: The situation was resolved by carefully considering all alternatives and getting all agencies involved. They eventually decided to put false work under the bridge and allow commercial

navigation to continue with that in place. They have been working on that, but Marian Havlik found a Higgins' eye where the false work was to be placed and I am unsure of what the outcome will be.

Table 1

Results of Corps of Engineers Mussel Surveys

Conducted by Brail on 5 August 1980

Mile	Run	Catch No.	Common Name	Scientific Name
617.5	1	1	Threeridge	*Amblema plicata*
		1	Maple Leaf	*Quadrula quadrula*
	2	1	Pocketbook	*Lampsilis ventricosa*
		1	Threeridge	*A. plicata*
		1	Pimple Back	*Quadrula pustulosa*
		1	Higgins' Eye	*Lampsilis higginsii*
	3	2	Maple Leaf	*Q. quadrula*
	4	1	Threeridge	*A. plicata*
		2	Pimple Back	*Q. pustulosa*
	5	30	Threeridge	*A. plicata*
		4	Pig Toe	*Fusconaia flava*
		2	Floaters	*Anodonta grandis*
		1	Washboard	*Megalonaias gigantia*
	6		Negative	
619.0	1		Negative	
	2		Negative	
	3	1	Pimple Back	*Q. pustulosa*

Table 2

Results of Corps of Engineers Mussel Surveys Conducted by Brail on 17 September 1980

Run	Catch		
	No.	Common Name	Scientific Name
1		Negative	
2		Negative	
3		Negative	
4	1	Threeridge	*Amblema plicata*
	2	Maple Leaf	*Quadrula quadrula*
	1	Pigtoe	*Fusconaia flava*
5	1	Wartyback	*Quadrula nodulata*
6	2	Threeridge	*Amblema plicata*
7		Negative	
8		Negative	
9	1	Maple Leaf	*Quadrula quadrula*

Table 3

Mussel Species Collected by Corps of Engineers Divers on 27 October 1980 from Within the Original 100- by 400-ft Rehandling Area (Site 3) at McMillan Island

Common Name	Scientific Name
Threeridge	*Amblema plicata*
Pigtoe	*Fusconaia flava*
Butterfly	*Ellipsaria lineolata*
Threehorn	*Obliquaria reflexa*
Pimpleback	*Quadrula pustulosa*
Fragile Papershell	*Leptodea fragilis*
Hickorynut	*Obovaria olivaria*
Wartyback	*Quadrula nodulata*
Pocketbook	*Lampsilis ovata ventricosa*
Maple Leaf	*Quadrula quadrula*
Giant Floater	*Anodonta grandis*

Table 4

Mussel Species Collected on 28 October 1980 by Corps of Engineers Divers from Within a 100-ft-Wide Border Around the Perimeter of the Rehandling Site (Site 3, Figure 8)

Location	Common Name	Scientific Name
Downriver border of the original rehandling site	Threeridge	*Amblema plicata*
	Hickorynut	*Obovaria olivaria*
	Fawnfoot	*Truncilla donaciformis*
	Pimpleback	*Quadrula pustulosa*
	Maple Leaf	*Quadrula quadrula*
	Threehorn	*Obliquaria reflexa*
	Wartyback	*Quadrula nodulata*
	Rockshell	*Arcidens confragosus*
	Pigtoe	*Fusconaia flava*
	Paper Floater	*Anodonta imbecillis*
	Pocketbook	*Lampsilis ovata ventricosa*
	Higgins' Eye	*Lampsilis higginsi*
	Mucket	*Actinonaias carinata*
	Pink Heelspliter	*Properta alata*
	Fat Mucket	*Lampsilis radiata siliquoidea*
	Monkeyface	*Quadrula metanerva*
Upriver border of the original rehandling site	Threeridge	*Amblema plicata*
	Pimpleback	*Quadrula pustulosa*
	Pink heelsplitter	*Proptera alata*
	Maple Leaf	*Quadrula quadrula*
	Pocketbook	*Lampsilis ovata ventricosa*
	Wartyback	*Quadrula nodulata*
	Hickorynut	*Obovaria olivaria*
	Pigtoe	*Fusconaia flava*
	Floater	*Anodonta grandis*
	Threehorn	*Obliquaria reflexa*
Channel-side border of the original rehandling site	Threeridge	*Amblema plicata*
	Hickorynut	*Obovaria olivaria*
	Threehorn	*Obliquaria reflexa*
	Ohio River Pigtoe	*Pleurobema cordatum*
	Pocketbook	*Lampsilis ovata ventricosa*
	Floater	*Anodonta grandis*
	Maple Leaf	*Quadrula quadrula*

Inclosure 1

The following is from

Endangered Species Technical Bulletin

September 1978, Vol III, No. 9

Department of the Interior,
U. S. Fish and Wildlife Service,
Endangered Species Program,
Washington, D. C. 20240

Dredging Hazard

Corps/Service Cooperate To Protect Endangered Mussels

One evening in early August, Jim Engel found a message awaiting him at home to call Sam Fuller at once, no matter how late the hour. Engel, the U.S. Fish and Wildlife Service's Region 3 endangered species specialist based at Minneapolis-St. Paul, imagined what the call was about before he picked up the telephone. There had been other urgent calls like this one from Fuller—all concerning new finds of endangered mussel specimens in the upper Mississippi River system. A malacologist with the Academy of Natural Sciences of Philadelphia (ANSP), Fuller has been surveying portions of the river's navigational channel scheduled for dredging by the U.S. Army Corps of Engineers. Under a unique contingency plan agreed to by the Corps and the Service, Fuller has instructions to call Engel and Corps officials as soon as endangered mussels are located, so that measures can be taken to protect them from the dredges.

On this occasion, Fuller informed Engel that he had found five Endangered Higgins' eye pearly mussels (*Lampsilis higginsi*) in the St. Croix River near the Hudson (Wisconsin) railroad bridge (about 25 miles upstream from where the St. Croix joins the Mississippi). The five specimens had been taken from a pool not far from where Fuller's crew discovered two other Higgins' eyes in 1977.

Under the contingency plan, dredging scheduled for this site would be temporarily stayed to prevent the imminent destruction of protected mussels while permitting an evaluation of the effects of dredging and the consideration of available alternatives.

In Effect Since 1977

Essentially, the agreement is an interim approach to promoting Corps compliance with Section 7 of the Endangered Species Act of 1973—a provision that requires all Federal agencies to ensure that their actions do not jeopardize Endangered or Threatened species or destroy or modify habitats considered to be critical to the species' continued existence.

In effect since the culmination of the survey in June 1977, the contingency plan is representative of the Corps' comprehensive effort to study Endangered mussels of the upper Mississippi to insure that channel maintenance will not have an adverse impact on any listed species or subspecies.

Jack Hemphill, former Twin Cities regional director for the Service, considers the actions of the Corps' St. Paul District since initiating consultation in January 1977 as exemplary: "In view of the potential ramifications this particular consultation presented, and the results accruing from the cooperative effort, I believe this consultation should serve as a model of how section 7 of the act should be administered."

The Corps of Engineers has been dredging the upper Mississippi to maintain a 9-foot navigational channel for over 50 years. Estimates put last year's river traffic in commercial cargo in the district at nearly 20 million tons, both up- and down-bound. During its 220-day navigational season, the Corps dredges an average of 6 percent of the 284 river miles in its St. Paul District. Some 20 sites must be dredged either annually or every other year to clear a path for the continuous flow of such commodities as coal and grain commonly shipped by barge.

Source of Controversy

In 1976, a few months after the Higgins' eye and fat pocketbook (*Proptera capax*) pearly mussels were listed by the Service as Endangered (F.R. 6/14/76), a private citizen complained that the Corps' dredges had killed a Higgins' eye in the Mississippi River's east channel at Prairie du Chien, Wisconsin. She charged the agency with violating section 7.

Prior to the complaint and even prior to the final listing of the species, the Corps had met with the Service, local government officials, and concerned citizens to notify them of its intent to dredge the channel and to discuss possible impacts. The Great River Environmental Action Team (GREAT), an interagency group of Federal and state representatives (see accompanying story), consulted commercial clammers to determine locations of clam beds and, in July 1976, visited the sites. This resulted in a modification of the dredging design to reduce the possibility of damage to known or suspected clam beds.

Following its review of the proposed operations, the Service determined that reasonable precautions were being taken by the Corps to insure that endangered mussels would not be jeopardized.

Study Launched

But the incident showed that knowledge of the status and distribution of the Higgins' eye was very limited, as was information on the abundance, distribution, and ecological requirements of the other 48 mussel species and subspecies known in the upper Mississippi. Accordingly, in keeping

(continued on next page)

Photo by Joseph E. Havlik

These Higgins' eye specimens, chipped from a dredge pipe in the Mississippi River's east channel near Prairie du Chien, prompted Marion Havlik to charge the Corps of Engineers with a Section 7 violation.

Mussels (continued from page 3)

with its section 7 responsibilities—and as a key member of the GREAT seeking to restore the river's multiple wildlife and recreational resources—the Corps decided to undertake a comprehensive study of freshwater mussel ecology to determine the effects of dredging and channel maintenance.

The need for the study was further underscored by a threshold examination conducted in February 1977 by the Service (following the initiation of formal consultation by the Corps), which concluded that:

- Maintenance dredging may jeopardize the continued existence of the species and/or adversely modify the habitat that may be determined critical to the species.
- Sufficient information did not exist at the time to determine Critical Habitat for the species.
- To make a biological judgment as to whether or not maintenance dredging would modify the Critical Habitat, it would be necessary to determine the location and extent of existing clam beds. Further, to determine whether maintenance dredging has jeopardized the continued existence of a species, it would be necessary to understand *the effects of siltation on mollusks.*

Dredging Effects "Minor"

The independent 2-year study effort —designed with the assistance of the Service, the States of Wisconsin and Minnesota, and the ANSP—was started in mid-July 1977 by Fuller, a recognized authority on mussels, under a contract with the Corps. Working through mid-November, Fuller surveyed 46 sites that had a history of dredging or were scheduled for dredging, including 42 sites on the upper Mississippi, 3 on the Minnesota River, and 1 on the St. Croix River, with cursory examination of a dozen additional *locations.*

At each sampling site, observations were made on its physical and biological condition, on the nature of the mussel community, and on the possible effects of channel maintenance.

After the first year of study, investigators tentatively concluded that channel dredging and associated activities "have only a minor impact on freshwater mussels, including the legally protected species" and that with careful planning the impact could continue to be minor. For example, Fuller noted that the two Higgins' eye specimens found in the St. Croix River during the study were only a few meters from where the navigational channel had been dredged in 1970, yet both were old enough to have been there prior to that time.

Confirmed adverse effects of dredging on *Lampsilis higginsi,* the study reported, were found only at Prairie du Chien, where 21 specimens had been lost in dredging operations, and on the Mississippi at Brownsville (Minnesota), where one juvenile specimen had been *located.*

But the study cautioned that, unless care was exercised in the removal of materials from the channel and in its deposition on spoil banks along the river, mussels could be adversely affected. The potential impacts include direct destruction of the animals by the dredges' cutterheads and subsequent transport through pipes to a new location; the burial of mussels under dredged deposits; and, increased turbidity and pollution through the resuspension of heavy metals and other

(continued on next page)

Great River Studies Striving To Conserve Fish and Wildlife

Preservation of endangered freshwater mussels is one of many concerns of the Great River Environmental Action Team (GREAT)—a Federal/state interagency body that is performing intensive studies of *the upper Mississippi River.*

GREAT was created in 1974 under the auspices of the Upper Mississippi River Basin Commission to investigate environmental concerns arising out of the dredging and maintenance of the 9-foot navigational channel by the U.S. Army Corps of Engineers from New Orleans to Minneapolis–St. Paul. Approximately 1 million cubic yards of sediment are removed from the river system annually and deposited in shallow backwater areas, on natural islands, or on spoil banks along the river.

Numerous wing dams have been *constructed by the Corps at right* angles to the river to control water flow. There also has been a considerable amount of construction and dredging by private interests.

These manmade changes have greatly altered the character of the river since 1924, when Congress proclaimed "navigation" as the river's primary purpose. That same year, Congress also established the Upper Mississippi River Wild Life and Fish Refuge, near Wabasha, Minnesota, but stipulated that operation of the 195,000-acre refuge was not to interfere with the operation of the 9-foot navigational channel.

Over the years, however, conservation organizations, officials of states adjoining the river, biologists, and interested individuals have become increasingly concerned about the river's alteration. Their campaign to give equal attention to such other aspects as fish and wildlife, recreation, wilderness areas, water quality, and flood plain management has led to the formation of GREAT.

The interagency team is made up of appointed representatives from the States of Wisconsin, Minnesota, Illinois, Missouri, and Iowa. The five Federal agency members are the Fish and Wildlife Service, the Corps of Engineers, the Department of Agriculture's Soil Conservation Service, the Environmental Protection Agency, and the U.S. Coast Guard.

Congress has appropriated nearly $10 million for a series of studies by GREAT from fiscal year 1975 through fiscal year 1979. These studies have been broken down geographically into three phases and cover every aspect of the river system's resources and management. GREAT I extends from Minneapolis–St. Paul south to Guttenberg, Iowa; GREAT II stretches from Guttenberg to Saverton, Missouri; and GREAT III covers the system from Saverton to the mouth of the Ohio River at Cairo, Illinois.

The main stem of the Mississippi, which drains 1.5 million square miles of land covering 31 states and two Canadian provinces, is the largest environmental "corridor" in the United States sustaining abundant fish and wildlife resources. But GREAT studies are showing that the biological productivity of the upper Mississippi is being threatened in a number of ways.

Continuing sedimentation is filling lakes, marshes, and backwaters. The disposal of dredged materials in some instances has resulted in the conversion of productive fish and wildlife habitat into relatively sterile open sand areas. Some backwaters created by the construction of dams and the diking effect of spoil banks formerly provided rich habitat for mammals, fish, and waterfowl. But now many of these same areas appear to be dying for lack of fresh water and for other complex ecological reasons.

It is disturbing problems like these, along with the conservation of fish and wildlife resources in the river's mainstream, that the GREAT studies are striving to correct before it is too late.

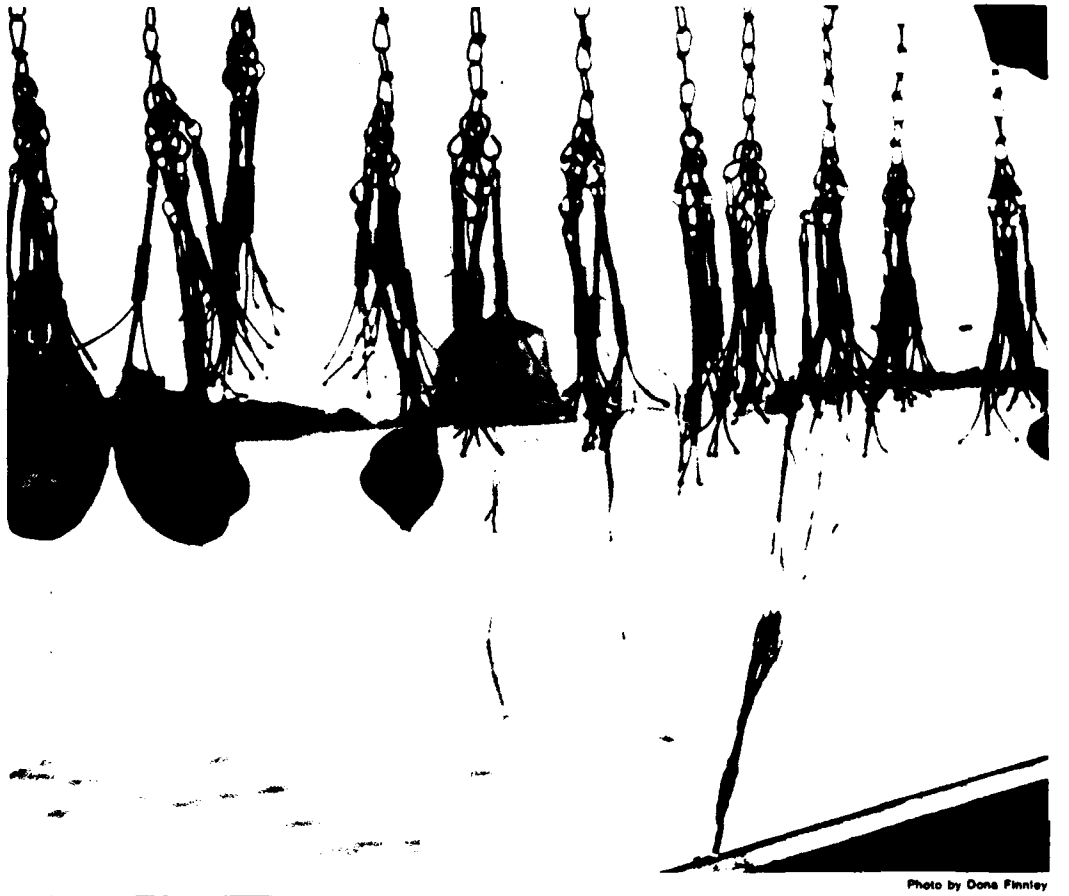

Photo by Dona Finnley

This sampling of freshwater mussels was pulled from the St. Croix River by Samuel Fuller just below the Hudson (Wisconsin) railroad bridge (in background), where he previously found six Endangered Higgins' eye pearly mussels. The mussels are clinging to a device known as a brail, which Fuller's crew has used extensively in its survey of dredging sites along the upper Mississippi River navigational channel for the U.S. Army Corps of Engineers.

The brail consists of a 10-foot wooden bar equipped with a number of 10-inch chains from which are suspended bunches of hooks. The hooks are straight wire tines of different gauges (to accommodate various sizes of mussels) tipped with balls of solder. The bar is designed to float above the riverbed while towed from a small boat, allowing the hooks to graze the bottom. As a hook passes between the open valves of a mussel, the animal clamps shut on it and is pulled along by the motion of the brail and boat.

In Fuller's brailing runs, the device is towed downstream for five minutes, then lifted into the boat so that specimens can be removed. Several 5-minute runs covering about 500 feet are made at each survey site, generally about 50 feet from the shoreline.

Mussels also are retrieved in the survey by pollywogging—wading offshore and collecting by hand; by scooping them up in a wire mesh box called a Needham scraper (useful for finding juveniles too small to be caught by brailing); and by hard-hat HOOKAH diving. The latter technique permits the visual examination of suspected endangered mussel beds without disturbing them.

Mussels (continued from page 4)

toxic materials when the river bottom is disturbed.

Turbidity reduces light penetration, decreasing the productivity of microorganisms upon which mussels feed, according to Fuller. Associated suspension of fine particles also may interfere with the animals' feeding and respiration by clogging their gills.

(Under agreement with the Minnesota Pollution Control Agency, the Corps is now studying the effects of turbidity, in terms of duration and extent of dissipation, and is attempting to determine the degree and nature of chemical pollutants resuspended during dredging.)

Project investigators also noted that backwater areas created by spoil deposits since 1924, when Congress authorized maintenance of the navigational channel, serve as prime nursery

(continued on next page)

Photo by Dona Finnley

Daniel J. Bereza, assisting Sam Fuller in the survey project, holds two specimens believed to be Higgins' eyes

Mussels (continued from page 5)

and breeding grounds for several mussel species and their host fishes, and may need special protection.

Restrictive state laws now preclude the open water dumping of dredge spoils along the upper Mississippi. Disposal is now generally made in consultation with states and other concerned agencies and organizations. Although so-called spoil islands are the primary dump sites, spoil is often used as landfill, for sanding icy roads, or as blacktopping.

Siltation Study

Another study—performed in 1977 by the Service under contract with the Corps—indicates mussels are capable of surviving burial under dredged silt to some degree.* Researchers demonstrated this by burying fat mucket (*Lampsilis radiata luteola*) and pocketbook (*L. ventricosa*) clams in sediment from 2 to 10 inches in depth. They found that 7 inches or more of sand or silt was required to prevent the emergence of the two species, while 4 inches of silt was sufficient to kill 50 percent of the smaller pigtoe (*Fusconaia flava*) clams.

Declining Populations

The Fuller study reveals that all species of mussels have suffered a decline in abundance in the upper Mississippi River over the past 75 years. (An exception is the mapleleaf—*Quadrula quadrula*—which has apparently managed to flourish by exploiting the impounded backwater areas.) There was no evidence of mussels in the lower Minnesota River, where they were abundant in the late 19th century.

Fuller attributes the sharp drop in numbers of several species, including the Higgins' eye, partly to excessive commercial exploitation by the pearl button industry, which used mussel shells to make buttons around 1900.

Probably all mussels have been affected by water quality degradation from municipal and industrial wastes, pesticide runoff, and increased siltation. Dredging and disposal of riverbed material by private companies was listed as another adverse factor.

Specimen Findings

Fuller's crew of 16 surveyors collected more than 8,500 living mussels during 1977, providing a cross-sectional sampling of the river's freshwater mussel fauna. From their scarcity, Fuller concluded that an "unfortunate number" of mussel species were in decline and probably facing extinction—among them the buckhorn (*Tritogonia verrucosa*), bullhead (*Plethobasus cyphyus*), and elephant ear (*Elliptio crassidens*).

No trace was found of the Endangered fat pocketbook. The study said this species "may linger in the backwaters, but its presence in the Upper Mississippi River in 1977 was in question." Similarly, no specimens were located of the rare narrow papershell (*Leptodea leptodon*)—also called the scale pearly mussel— and salamander mussel (*Simpsoniconcha ambigua*). The status of the narrow papershell is under review for possible listing under the Endangered Species Act.

Another rare species, the spectacle case mussel (*Cumberlandia monodata*), was discovered at two sites. This species apparently can live in wing dams that have been built at right angles to the shore to control the flow of the river.

Exotic Intruder

The study discovered the presence of an exotic species—the Asiatic clam (*Corbicula manilensis*)—in the St. Croix River. The species is known to dislodge mussels from the streambed, uprooting them to their eventual death. Fuller said if the Asiatic clam becomes established in the beds where the Higgins' eyes are located and elsewhere, it could pose as big a threat to the mussel population as any of the other adverse factors.

Parasitic Phase

An associated problem is the availability of the proper fish species to serve as glochidial hosts. Many species of freshwater mussels reproduce by the male shedding his sperm into the current; the sperm is then picked up downstream by the female whose eggs become fertilized as they are extruded from the oviducts. The fertilized eggs are held in the gills, where they develop into larval forms known as glochidia.

In some genera, the glochidia develop into juveniles while still in the mussel's gills. But in others, such as *Lampsilis*, the glochidia attach themselves to the gills and body of a passing fish. The larval bivalve then soon becomes covered by fish tissue, which forms a cyst or capsule. After its metamorphosis in this parasitic stage, a juvenile mussel then drops from the fish to the stream bottom, where it grows to adulthood.

Fuller believes further research is needed into the glochidiosis process as no larval hosts have been identified for three of the rare mussels.

Biological Opinion Due

Additional information gathered during this year's survey effort will be available in the form of a second report around the first of the year. These and related data will then be employed by the Service in preparing its biological opinion on the overall impacts of the Corps' channel maintenance operations, which the Service expects to issue by early spring.

Photo by Dona Finnley

Samuel L. H. Fuller, the malacologist selected by the Corps to lead its survey effort, examines a pigtoe mussel

* Leif L. Marking and Terry D. Bills, "Acute Effects of Silt and Sand Sedimentation on Freshwater Mussels," FWS Fish Control Laboratory at La Crosse, Wis., 1977.

INVOLVEMENT OF THE U. S. ARMY ENGINEER DISTRICT, LOUISVILLE, WITH FRESHWATER MOLLUSKS

by

John S. Kessler*

Abstract

Personnel in the Louisville District Office, Louisville, Kentucky, became interested in mollusks as a result of litigation concerning two proposed lake projects in Ohio. Increased interest and involvement with mollusks were stimulated by the 1978 amendments to the Endangered Species Act. In-house capability in sampling and identification was developed by personal studies, trial and error, and discourses with professional malacologists and a commercial brailer. District personnel have conducted numerous small field assessments for mollusks in addition to involvement with a contracted study on the lower Ohio River in the summer of 1980. Although eight species of endangered mollusks are reported to exist within the boundaries of the Louisville District, none have been collected to date. Coordination with the U. S. Fish and Wildlife Service on the above studies has been excellent. Based upon personal experiences and opinions of others, further work on sampling methodology and species identification is needed.

Introduction

Concern with freshwater mollusks at the U. S. Army Engineer District, Louisville, was generated in 1974 as a result of comments received on the draft Environmental Impact Statements for East Fork and Caesar Creek Lakes. Both of these proposed lake projects, located in Ohio, were in litigation with regard to alleged District nonconformance with the National Environmental Policy Act (NEPA). Although the litigations were resolved in favor of the District, several valuable lessons were learned. One of these was that considerations involving impacts to freshwater mussels were going to become increasingly significant in environmental assessment and impact analysis. Although environmental assessments included consideration of endangered species and our EIS's referenced the Endangered Species Act of 1973, the enactment of the Endangered Species Act Amendments of 1978 provided additional significance to our need for dealing with freshwater mollusks. That legislation resulted in establishment of formal procedures for endangered species coordination and formal consultation if necessary with the U. S. Fish and Wildlife Service. In recognition of this, District Staff

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began to develop the capability for assessment of freshwater mollusks and identified coordination paths with the FWS.

Development of Program

Development of the capability with freshwater mollusks involved various considerations. We had some knowledge of mussels gained from academic backgrounds and previous work. However, no one was a malacologist. Upgrading in this field involved concentrated library work, a private study (Kessler and Miller 1978), and discourses with authorities; in this respect we are indebted to Dr. David Stansberry of Ohio State University who graciously made his collections and himself available. Our brailing technique was developed from library research, trial and error, and from working for a commercial brailer in exchange for learning the trade. In addition, Mr. James Peach of the American Shell Company provided brail hooks and a discussion on methods of musseling. Mr. S. L. H. Fuller, of the Philadelphia Academy of Sciences, sent information on sampling methods and directions for brailing. Establishing rapport with the Endangered Species arm of the FWS was not difficult. These people, including those at the Wildlife Permit Office in Washington, D. C., made every effort to facilitate reasonable and productive coordination.

Present Program

Currently, the Louisville District work with mussels involves Sections 10, 14, and 404 permit investigations and assessments for District studies, such as navigation, hydropower, and flood control. Our endangered species coordination is carried out with Regions III and IV of the FWS.

The bodies of water within the Louisville District which possess notable mussel populations are the Green River of Kentucky, the White and Wabash Rivers in Indiana, and the reach of the Ohio River which extends from Greenup, Kentucky, to Cairo, Illinois. Collectively, these streams and their tributaries are, based on the literature, supportive of eight species of endangered unionids. In addition, there is the uncommon and non-unionid *Cumberlandia monodonta*. Commercial mussel operations have in recent years been noted to occur on the Lower Ohio, the Lower Wabash, and pools 4 and 5 of the Green River. There is an apparent upswing in commercial utilization of this resource as compared with the early 1970's.

Base data of the occurrence of mussel beds are incomplete. The only major study of the area was made by Williams (1969) of Eastern Kentucky University on the Ohio and Green Rivers. This study, done in 1967, has been generally accepted as the definitive study for these streams.

We also used Parmalee (1967) and Starrett (1971) which involve the State of Illinois and, from a historical perspective, have found Coker (1921) informative.

It is also our policy to require mussel information from major permit applicants, most notably power plants, as part of required environmental assessment work. This contributes to a complete EIS and enhances our knowledge of contemporary mussel beds. We do mainly in-house surveys utilizing our own capability. For a study of a proposed canal from Carmi, Illinois, to the Ohio River and a study for Lower Ohio navigation, consultants have been used. In general, work performed by District employees consists of spot-check brailing of bank protection projects or similar sites. The only notable exception to this was a field study conducted by District staff which involved several pools of the Green River.

The Louisville District is now cooperating in a major mussel survey of the previously referenced reach of the Ohio River. The study is anticipated to begin in 1982. It is felt that the survey will provide a current and comprehensive base from which to promulgate management, planning, and permitting decisions with regard to notable mussel beds and the possibility of occurrences of endangered species. The funds for the contract are to be provided by the Corps of Engineers, the FWS, and the Commonwealth of Kentucky. The work will provide insight into the location, extent, composition, and recruitment potential of mussel beds, as well as the substrate on which each bed is located. Brail will be the principal collection method.

To date no endangered species have been found during District studies. Perhaps this is not the true picture; however, it does tend to lend weight to the belief that many endangered mollusks were not particularly abundant during historical times. It also emphasizes that successful collection of endangered mussels requires concentrated effort and perhaps innovative methodology. There is no doubt that a few reconnaissance tows over a possible mussel bed, especially while using a short bar brail, may not collect endangered species. Such brails are invaluable aids for location of mussel beds but are not quantitative.

With regard to our work with the FWS, the relationship is generally good between the District and endangered species personnel. These people do react positively to interest displayed by District personnel and to reasonable efforts to comply with requirements of the Endangered Species Act. Thus far, we appear to have considerable rapport with them and coordinate well, both formally and informally. We usually extend an invitation to FWS personnel to accompany us into the field. This contributes greatly to the professional rapport between our agencies.

Equipment

The brail bar used by the Louisville District is seasoned white oak, 2 by 4 in., about 1.6 m in length (Figure 1). The lines from the hooks are 1/8-in. nylon about 0.57 m in length. Nylon is used for safety reasons (see below). The brail is towed from the bow of a johnboat by backing slowly downstream in order that mussels will have maximum time to close on the hooks. We generally tow for five minutes and then lift the brail and check for mollusks. The wooden bar floats off the bottom and presumably does not stimulate closure of the mussels. It is worthy of note, however, that iron bars made of pipe are also used, and in the hands of a competent operator, are reasonably successful.

Figure 1. Brail bar used by Louisville District

Two sizes of hooks are used on the brail (Figure 2). The tips of the hook have been beaded by peening with a hammer or attaching a small lump of solder to the tips.

One problem that presents itself in making wood bar brails is the weight needed to assure that the hooks contact the bottom. One way to overcome this is to determine empirically the number of hooks required to sink a unit length (one foot for example) of a section of a bar. The minimum number of hooks or additional weight can then be calculated quite easily.

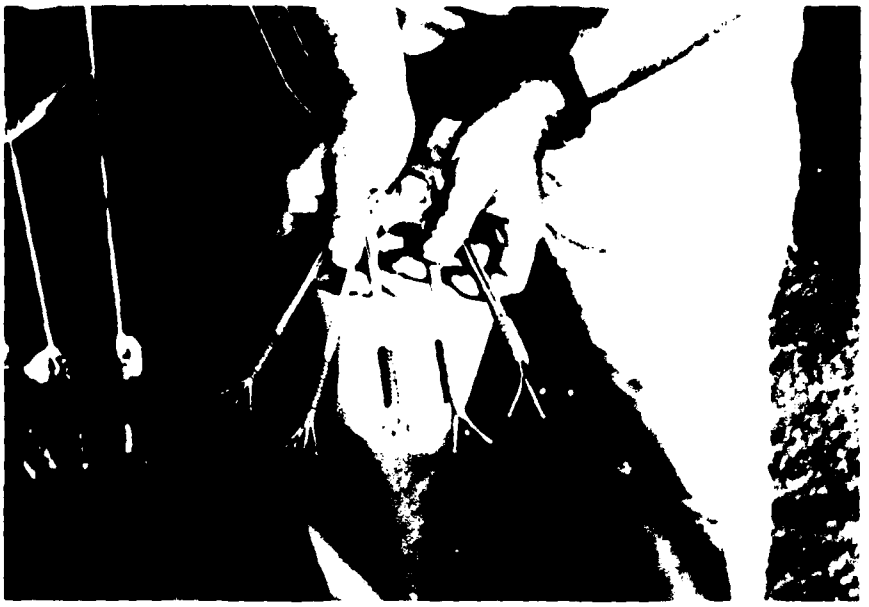

Figure 2. Two sizes of hooks used on the brail

The District brail differs in construction slightly from one used by Mr. S. L. H. Fuller, Philadelphia Academy of Sciences. We attached hooks with fairly long nylon lines. Based upon information provided through Mr. Fuller, the Philadelphia Academy's brail used fairly short chains. It is my unsubstantiated feeling that a longer length of the chain or line (which attaches hooks to the bar) will tend to keep the hooks from being jerked off the bottom and thus enhance chances of capturing mollusks. This might not be a terribly critical point; however, the commercial brails I have examined do appear to have long lines.

At the Louisville District we use a johnboat to tow our brail. A bow rail is useful for support of the brail when not in use and to secure the tow rope when operations are under way.

Commercial mussel boats operating on the Green River in Kentucky (Figure 3). These boats each use two iron bar brails which are deployed off the port and starboard sides alternately. Thus, while one brail is up the other one can be towed, permitting removal of mussels with no loss of fishing time.

The winch located in the center of Figure 3 operates both brails, and tow ropes are attached alternately depending on the brail chosen for tow. The towing method is by "mule." This is an underwater sail constructed of canvas and wood that is attached to the bow. The action of the current on the mule pulls the boat downstream despite the drag exerted by the brail. Steering is accomplished by varying the angle of

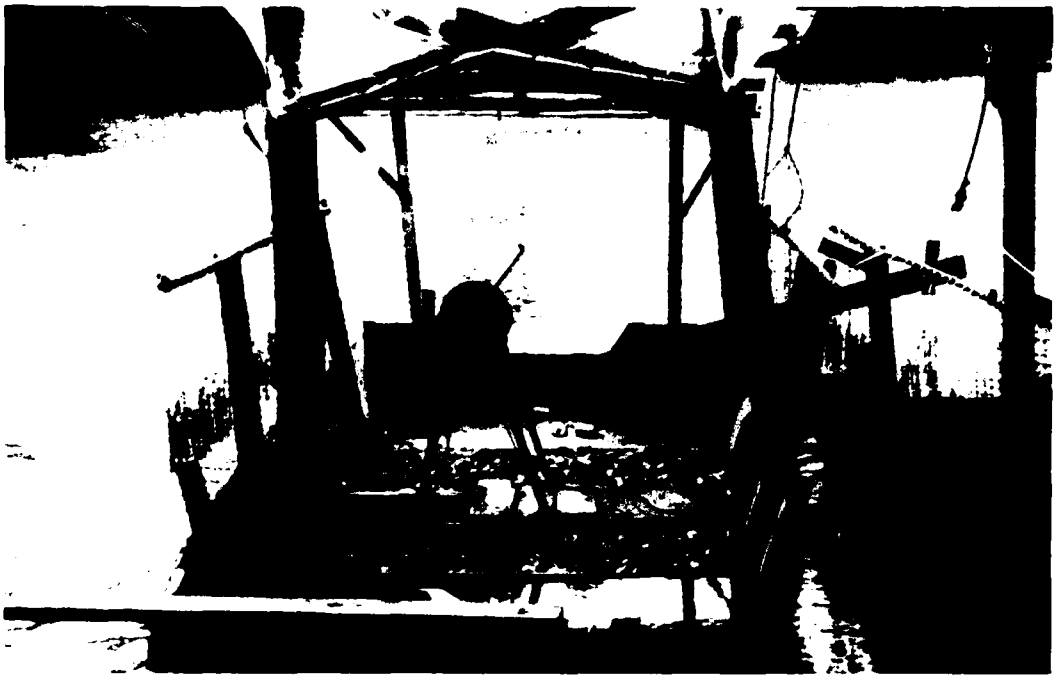

Figure 3. Commercial mussel boats operating on the Green River in Kentucky

the mule within the water. This procedure is very analogous to conventional sailing.

Hazards, Requirements, and Problems

There are potential hazards associated with brailing. The hooks, lines, and chains can tangle in clothing and, possibly, pull an individual overboard. A sheath knife should be worn in case rapid cutting is required. Also, it is recommended to wear clothing that will present less chance of entanglement. As previously noted, our brail has nylon lines and this enhances the possibilities of our being able to cut ourselves loose should we become entangled.

If collections for mollusks are to be legal, an appropriate State collecting permit is required. In addition, the principal collector should obtain a Federal Endangered Species Permit. These are available from the FWS Permits Office in Washington, D. C. Obtaining these permits can be time consuming (about two months for the Federal permit); therefore, it would be wise to apply well in advance of the field season (April through October). Typically, a Federal permit requires live release, on site, of endangered mollusks and forbids further brailing after discovery of the first living endangered mollusk. One can understand the reasoning behind such constraints; however, positive

identification based upon external features is not always possible.

Because of these difficulties it appears that there is a need, from the standpoint of both commercial operators and Federal and state biologists, for dissemination of information on field identification of endangered mollusks.

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DEVELOPMENT AND USE OF MUSSEL EXPERTISE WITHIN THE ROCK ISLAND DISTRICT

by

Thomas M. Freitag*

Abstract

To comply with the Endangered Species Act of 1973, several mussel surveys were conducted within the Rock Island District in the Upper Mississippi River from 1977 to 1980. These surveys ascertained the presence or absence of the federally endangered mussel species, *Lampsilis higginsi* and *Proptera* (=*Potamilus*) *capax*, and the potential jeopardy in which these species would be placed by Corps of Engineers' dredging activities or other actions. Contracted studies were originally the means taken by the District to survey for endangered species. To meet tight schedule requirements, Corps biologists developed expertise in mussel identification, survey and preservation techniques, and mussel ecology. Acceptance of District expertise by other agencies grew as the experience of District biologists increased. District biologists were able to accurately identify most mussel specimens and judge the probable jeopardy of Corps' action on an endangered mussel population. Corps biologists not only were able to survey sites where Corps action was proposed, but also assure that contracted surveys were adequate.

Introduction

Shortly after the listing of *Lampsilis higginsi* (Figure 1) as "Endangered" by the U. S. Department of the Interior in June 1976, specimens of this species were found during channel maintenance dredging operations of the U. S. Army Engineer District, St. Paul. As a Federal agency, it took steps to avoid destruction of this species. In order to better understand the effect of channel maintenance on endangered mussels, St. Paul District initiated the negotiation of a contract to survey various channel maintenance sites. The Rock Island District learned of the proposed contract and joined in this survey effort (reported in Fuller 1978). Since this survey in 1977 and 1978, additional studies at channel maintenance sites were conducted both within the St. Paul District (Fuller 1980) and Rock Island District (Freitag 1978 and Ecological Analysts, Inc. 1981). A number of other studies were also conducted by Rock Island District in project areas (Nelson 1979) and at sites where work was proposed by applicants for Department of the Army permits. These latter surveys were generally conducted for the

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applicant by a contractor with the results submitted to the District Office for evaluation.

Although the emphasis of these mussel surveys was to determine the presence or absence of *L. higginsi*, another federally endangered species, the fat pocket book (*Proptera* (=*Potamilus*) *capax* (Figure 2), was historically found in the Upper Mississippi River and all surveys were conducted with this species in mind. Other species considered rare were also sought, such as *Cumberlandia monodonta* and *Simpsoniconcha ambigua* (Fuller 1978 and Ecological Analysts 1981).

Development of District Expertise

The development of mussel expertise in Rock Island District came from the need of the District to meet provisions of the Endangered Species Act not to jeopardize endangered mussel species and at the same time to balance Corps' needs to accomplish mandated work. Initial steps in the development of personal expertise began in spring 1976 when the author started a collection of mussel valves found along the riverbank. After advice from the Fish and Wildlife Service (Ed Perry personal communication) reference books were obtained (Parmalee 1967, Starrett 1971, LaRocque 1967). Photographs of mussels and mussel descriptions in these references were compared with collected specimens and many of these mussels became part of the District reference collection.

Several malacologists were involved in mussel surveys after the presence of *L. higginsi* became known. These surveys were performed for the District Office and private industry. Their suggestions in matters of sampling, identification, and other aspects greatly increased the understanding of District personnel of mussels and mussel ecology. These malacologists included Mr. Samuel L. H. Fuller, Mr. John M. Bates, and Dr. David H. Stansbery.

Commercial clammers were also very helpful in giving their opinions on mussel collection and ecology. The practical experience of these people often spanned 40 years and they were knowledgeable about the presence of common and many uncommon species of mussels found in the reach of river they fished. Often specimens of uncommon mussels could be obtained from a clammer for addition to the District's reference collection.

Building of a synoptic collection for comparison with unidentified material aided identification of dubious material and added assurance to identifications. Juvenile and adult mussels, male and female mussels (in mussels exhibiting sexual dimorphism), and mussels from different ecological stations (stream, large river, and lake) were collected when possible to develop as complete a picture as possible of the range of variation of a species.

A review of the literature and museum material helped to establish what species were previously taken from the Upper Mississippi River basin. Some of the earliest references found included Tryon (1865), Pratt (1876), Marsh (1887-1889), Keyes (1889), Witter (1883) and Shimek (1888). Early collections (by H. A. Pilsbry and R. E. Call, etc.) housed in the Putnam Museum, Davenport, Iowa, also helped establish the faunal composition of the basin before this area had been modified to any extent. The most comprehensive survey of the main stem Upper Mississippi River was reported by van der Schalie and van der Schalie (1950). From the literature found and examination of early collections, it appears that about 50 species made up the original mussel fauna of the Upper Mississippi basin (above the junction of the Missouri River). Knowledge of species previously found helped ascertain where federally listed species might be expected and confirmed the presence of rare but unlisted species in the basin.

Acceptance of Expertise

Acceptance of the expertise of the District biologist in mussel identification (internally and by other agencies) grew as this ability was demonstrated. This acceptance is important to a District since mussel survey results are readily accepted and projects/actions are either not delayed (no endangered species found), or not unduly delayed. (Endangered species found, but suggestions for modifications of projects/actions accepted by the Fish and Wildlife Service and other agencies.)

Area of Concern

The District biologist/malacologist (in the experience of the author) is mainly concerned with correct identification of endangered species within the District, mussel ecology, and how to adequately sample mussel communities. Although a District biologist may not have the knowledge of an "expert" in areas such as anatomy, physiology, or in the identification of species outside the District, the District biologist has to deal with identification of only a portion of the mussel fauna of North America. Since most Districts are set up along drainage basin boundaries, the biologist will usually have a discrete portion of the North American fauna to learn, which greatly simplifies his task. In the author's experience, a District biologist can routinely identify mussels with high assurance that identifications are correct. However, certain specimens such as juvenile (4 to 6 mm) and atypical or damaged shells may need a second opinion as to a specimen's identity. Live specimens of suspected endangered species should be sent (with concurrence of responsible authorities) to an expert for his opinion. Fuller (personal communication) suggested air-shipment of mussels for identification with minimal chance of harm.

A District biologist usually is limited in time available to conduct a survey since it is likely he will have many other responsibilities. Contracting of surveys is often the most practial course to take especially when the proposed survey work is extensive with many sites and when there is no pressing need for the data. When selecting a contractor, the expertise of a contractor should be carefully scrutinized before selection. As discussed earlier, the accuracy of mussel identification and methods should be above reproach. To allow for future confirmation of specimens collected and future study, it is advisable that the contractor submit voucher material taken during survey work to a museum for permanent housing. However, live endangered mussels captured during a survey are usually not sacrificed for voucher material (depending on provisions of the individual Federal endangered species permit) and photographs must suffice for future reference. Examples of work undertaken by the author as a District biologist are summarized below.

The 1978 mussel survey

In mid-1978, Rock Island District recognized that a mussel survey was imminently needed at several sites in the Upper Mississippi River that were scheduled to be dredged. The contractor (Mr. Samuel Fuller) for the joint effort was then surveying several proposed dredging sites within St. Paul District and was unable to aid Rock Island District. Since contracting a mussel survey would have taken several months to accomplish, the District decided to conduct the survey itself. The sites that needed to be surveyed were scheduled to be dredged in less than a month from the time the District first determined the need for a survey. The possible need for a mussel survey had been foreseen and the District had purchased a mussel brail (crowfoot bar) (Figure 3) earlier in 1978. Other equipment and material had to be obtained prior to the start of the survey (Freitag 1978). Briefly, the following material was obtained: formalin, alcohol, sodium pentobarbital (mussel relaxant), empty 55-gal drums (to hold preserved mussels for eventual shipment), burlap sandbags (to hold separately preserved mussel lots), and ice chests (Figure 4) (to prevent premature death of specimens due to temperature stress).

In order to prevent any possible question as to whether specimens had been properly identified, it was decided that most specimens taken in the survey would be relaxed and preserved in a lifelike condition and sent to the Smithsonian Institution.

A total of seven sites were surveyed within a two-week period. Mussels were taken by brail or hand picked (Figure 5), if the river stage allowed and the substrate consisted of sand. Dead specimens were also picked from the bank (Figure 6) to demonstrate the former presence of mussel species at a site. Most dredge sites surveyed had few mussels and low species diversity and are chronic dredge sites where sand accumulates quickly and often threatens a closure of navigation. Proposed disposal areas surveyed often had diverse and sometimes numerous mussel populations. During the survey, it was decided that one disposal area

should not be used because of the large mussel population found (as compared with dredge sites).

No live endangered species were found during this survey. However, two relic valves of *P. capax* were found and subsequently sent to the Smithsonian Institution, as well as a drum of preserved mussels.

Contracted survey

One of the outcomes of the 1978 in-house survey was the realization within the District that endangered mussels potentially existed at several dredge sites within Rock Island District, and that a more extensive survey (than the in-house survey) was needed to adequately survey dredging sites which had a high dredging frequency.

Development of a scope of work for this survey was begun in late 1978 and the contract awarded in July 1979. Experience developed in the 1978 in-house survey and the joint work with St. Paul District were used in the design of the scope of work. Similar methods were employed in the contracted survey (Ecological Analysts 1981) including use of the brail and hand-picking of specimens. However, the contractor also used scuba (to obtain quantitative data) in mussel beds shown to have an endangered mussel population and used a modified Needham scraper (garden rake with 1/4-in. hardware cloth basket) to obtain juvenile specimens.

Thirty-two sites were surveyed in the 90 days provided in the contract. Several live specimens of *Lampsilis higginsi* were found in the course of the survey as well as several dead valves of *Proptera (=Potamilus) capax*. None of the *L. higginsi* found were in a dredge cut area, but two disposal areas were changed because of the possible jeopardy to populations of this species.

Conclusion

After the passage of the Endangered Species Act of 1973 and listing of mussel species as endangered, Corps Districts, as Federal agencies, must take into account the presence of endangered species that might be jeopardized by action of the Corps of Engineers. The development of expertise in mussel identification and sampling within Rock Island District increased the ability of this office to determine whether or not Corps actions would jeopardize a species. In instances where *L. higginsi* was found at disposal sites, alternate sites were chosen.

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Discussion

A. Clarke: Concerning a relaxant, you can use nembutal which is expensive. One method that I have found to be effective is to place a few clams in a plastic bag partially filled with water and then place everything in the freezer. The clams open and begin to siphon before the whole thing becomes a solid block of ice so the organisms are frozen in a natural position. Then I take out the ice and melt it and then preserve the clams in formalin, and I have naturally relaxed specimens without using a relaxant.

D. Nelson: I have placed saltwater clams in an ice chest filled with freshwater. These relax and open gradually. Have you ever tried this?

A. Clarke: No. The only other method I have used is with nembutal, which is not the best.

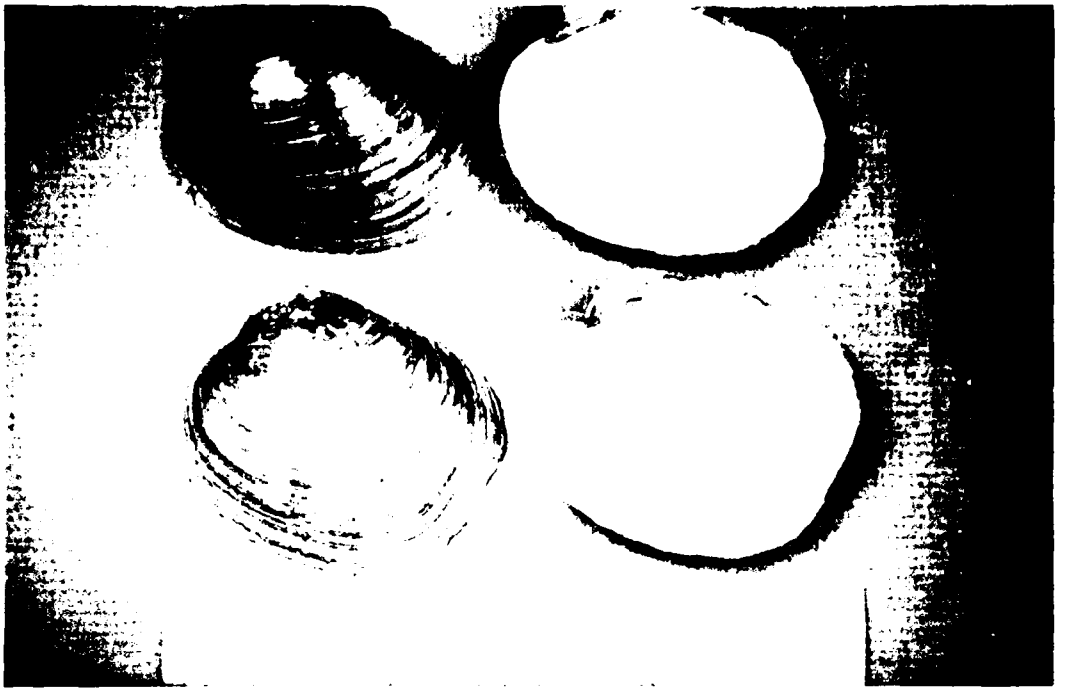

Figure 1. *Lampsilis higginsi*; top, male; bottom, female

Figure 2. *Proptera (=Potamilus) capax*

Figure 3. Brail (crowfoot bar) used in 1978 Corps survey

Figure 4. Ice chest with mussels collected in 1978 Corps survey

Figure 5. Results of hand picking for mussels in Pool 22

Figure 6. Bank collecting for historic mussel specimens in Keokuk, Iowa

MOLLUSK STUDIES UNDER WAY AT THE U. S. ARMY ENGINEER DISTRICT, MOBILE

by

Jack C. Mallory*

I am one of the people to whom the Endangered Mollusk Project and this Workshop is directed. My training as a malacologist began 30 years ago and lasted two days. I had collected mussels on the James River and then went to my University library and attempted to identify them. I had collected mostly shells which were lying in shallow water and along the shore. I quickly decided that life was too short for this and that there must be an easier way to identify shells. I was using a key which required knowledge of the internal or soft parts of the organism. You can imagine my consternation when I found out that I needed to know the reproductive state of certain gills in a gravid female and all I had was empty shells.

I did not really become interested in mollusks again until I started to work on the Tennessee-Tombigbee Project (TTW) in 1970. This project concerns the development of a navigation route connecting the Tombigbee River to the Tennessee River. The river section of this project is approximately 150 miles long requiring construction of four new locks and dams. The highest is 36 ft and the lowest is 27 ft. These impoundments are not lakes as such but run-of-the-river reservoirs, not for water storage but for navigation. The minimum depth of this channel must be maintained at 9 ft. As a result of this project, the current in the upper Tombigbee River will be slowed where the cross-sectional area of the river is increased near the dams. The upper portions of the river near the approaches of these dams should remain essentially the same as they have always been, albeit a little wider. Realize that the Tombigbee River throughout this project area is much smaller than the previously discussed Mississippi River where *Lampsilis higginsi* has been collected. At Columbus, Mississippi, the flow ranges from 200 cfs to about 194,000 cfs; this is a very dynamic system and is considerably smaller than the Mississippi or Ohio Rivers.

Two significant things happened at the Mobile District concerning the TTW and freshwater mollusks which rekindled my interest in this group of organisms. The first was that the adequacy of the District's Environmental Impact Statement (EIS) describing project-related impacts was questioned. During two weeks of discussion in court, nearly three days were spent considering the effects of the TTW on mollusks. There were many opinions expressed by eminent malacologists concerning possible impacts to mollusks. There was considerable confusion and contradiction in their testimony. Finally, the court concluded that the environmental impacts would be acceptable and that the EIS was adequate.

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Then, in the spring of 1980, the U. S. Fish and Wildlife Service (FWS) published a status review on five species in the Tombigbee River. They were requesting additional data on selected species (*Pleurobema curtum, P. marshalli, P. taitianum, Quadrula stapes*, and *Epioblasma* (=Dysnomia) *penita*)) which were known to be uncommon and possibly should be considered for Federal listing. As a result of the above concern about bivalves, I found myself becoming intensely interested in malacology.

My objective is to present a clear picture of the Mobile District's involvement with freshwater bivalves. As I indicated earlier, part of our problem has been with the lack of consistency among the experts. Now I fully understand the problems and limitation imposed by lack of time and funds; however, when even the experts cannot agree on what to call a specimen or whether or not this or that individual is a true species, then we have a problem. We have had two experts who provided different species names and different opinions on biological impacts, all very opinionated, but in conflict. This is difficult for me to understand, let alone the nonprofessional public or an engineer who is not a biologist. What I have described has occurred in and out of court on this project and has been an additional problem with which the Mobile District has had to contend.

For example, as part of our work we consulted the scientific literature concerning the five species under status review by the FWS. The first work was conducted by Issac Lea and Conrad in the 1800's with additional work done by Dr. van der Schalie in 1939. During this period, these five species had a variety of different names. To sort through these synonymies is a difficult, though not an impossible, task for a biologist who is not a professional malacologist. Another problem we encountered was that the majority of these early samples were taken where roads or railroads crossed the river. This is not surprising but simply illustrates that no scientifically designed survey has ever been conducted in this area. Dr. Williams' survey in the 1970's was the first intensive study of the river. However, his work was in no way complete since he did not fully study the tributaries.

Based upon the past studies, the five status review species have been found in the Tombigbee River. These five are reported to be large river forms and should not be collected from tributary streams. What this really means is that these species have been found historically only in gravel areas in the main river.

In 1974, with the assistance of Dr. Paul Yokley, University of North Alabama, the Mobile District conducted a mussel survey on portions of the Tombigbee River. We established sampling stations along transects located above and below each proposed damsite and halfway up each future pool. Our objective was to identify the extant macrobenthos before development of the TTW and to establish reference stations and baseline data for postproject investigations.

As a result, some 40 species of naiads were identified, including

the five status review species. In another study, conducted on a 69-mile stretch of the Buttahatchie River, Dr. Paul Yokley collected a total of 45 species of mussels. Of particular interest was the fact that he collected 60 specimens of *Epioblasma (=Dysnomia) penita*. This was one of those supposedly restricted to the main river. This raises a question as to whether or not this species, or others, might be, in fact, tributary or headwater species and are only occasionally found in the main river. In addition, we have collected *P. taitianum* in the lower part of the Buttahatchie River and Schultz and Pierson collected it in Bull Mountain Creek. Dr. Yokley found *Quadrula stapes* in the Sipsey River, another tributary of the Tombigbee River. At this point, three of the five status review species have been found to exist in the tributaries although their geographic range has not been shown to be much different than was previously thought. We have shown that their ecological requirements can be met in these tributaries. On the other hand, *Pleurobema curtum* has not been found recently in the Tombigbee River. It may be a hybrid or an ecomorph. All that is known for certain about its status is that it has always been rare.

In addition, we have collected mussels in the tributaries entering the Tombigbee River from the west. While it was said earlier by Dr. Williams that these streams, because they are intermittent and were channelized 30-40 years ago, do not contain mussels, this is not true. Throughout this area, during low flow periods there are abundant mollusk tracks in the wet sand. At the end of each track, there is usually a living mussel sometimes a foot beneath the surface. There are at least five or six different species in these tributaries, including *Amblema* sp. Obviously, this area needs further study. Some of the status review species may be there, although we simply do not know for sure.

As everyone is aware, the knowledge of life cycles and requirements for the naiad mollusks, with the exception of a few species, is very scarce. This is particularly true when you try to find specific information on the very rare species. Concerning work at the Mobile District, we may have altered the habitat of some of these species. The Columbus Lock and Dam was closed in January 1981. We are now in a position of trying to preserve and enhance the remaining habitat with our limited knowledge about these organisms. For example, we do not know what will happen when the water levels increase by 20 ft. Common and uncommon mussels may be unimpacted or on the other hand they may survive in the area, but not successfully reproduce.

It is our objective to make the TTW as environmentally acceptable as possible and still meet the navigational needs of the region. We are enhancing the positive and attempting to ameliorate the negative impacts. In addition, I feel strongly that the overall biomass of the aquatic biota should be maintained and/or increased if at all possible. Along these lines, we have contracted with WES to develop a design for a gravel bar habitat that can be used by mollusks, fish, and other benthos. Gravel substrate has never been an abundant commodity in the river, so we want to create this type of habitat below the Columbus Lock and Dam

in the old river channel of the Tombigbee River. This should increase biomass and the diversity in this reach of the river.

In addition, we hope to keep the natural bendways in the river open for aquatic habitat. In this stretch of the river there are approximately 30 bends which have been cut off or shortened for navigational purposes. If we can keep these areas, which are not going to be used for navigation, freely flowing, then the aquatic biota such as mollusks, fish, and aquatic insects, will certainly benefit. Also, we have added devices to the dams to attempt to increase oxygen levels. Water quality in the system will in all likelihood not be a problem; nevertheless, we have endeavored to improve it.

Concerning maintenance dredging, material removed from the river has been placed in two-celled, diked areas located at least 300 ft from the water's edge. Vegetation was left intact in this 300-ft buffer zone in order to maintain the forest cover in contact with the aquatic system. Most coastal plain rivers in our district derive their biological energy from detrital input. Due to high turbidities, phytoplankton is not the basis of the food web.

Finally, we are taking a hard look at the commercial gravel dredging operations in the river and their potential impact on mollusks and other macrobenthos.

If any of the five status review species are placed on the Federal list there would not be a problem as far as the project is concerned. However, the required maintenance dredging could negatively impact mussels and other macrobenthos, so we are working to preserve the more productive substrates in the system.

FRESHWATER MOLLUSKS, THE COMMERCIAL APPROACH

by

James L. Peach*

I certainly appreciate the opportunity to attend this workshop and be a part of these discussions. This is probably the first truly objective approach to the problems associated with freshwater mussels that I have seen. It is my feeling that the commercial clamming industry does have a lot to offer to the scientific community and the Federal biologists concerned with these problems. Let me illustrate by asking this question: How many of you know the types and amount of shells that could be collected from the Grouse Creek in Kansas, the Ouachita River in Louisiana, or the St. Angelina River in Texas? My company has records for all of these areas and many more. We have spent literally tens of thousands of dollars investigating the commercial shell market in this country. Certainly, some of this information would be of value to the Corps of Engineers, university people, and other Federal biologists.

Let me begin by providing some background on my work and then leave the rest of the time for questions. Our company, the American Shell Company, in Knoxville, Tenn., is one of the two largest commercial shell companies in the United States. The other company is the Tennessee Shell Company in Camden, Tenn. We handle approximately 2000 tons of dry shells a year. Most of these are exported to Japan or other eastern countries for processing and eventual use as the nucleus in the growing of cultured pearls. Most of these shells are the giant Washboard (*Megolonias giganti*). Today, this is the major shell used by commercial industries.

Back in 1966 and 1967, there were approximately 25,000 tons of shells produced in this country for export. Of that 25,000 tons, about 99 percent were collected from free-flowing streams or channels with running water. However, in 1980 the exports amounted to about 4,700 tons. I estimate that 85 percent of these shells came from impounded rivers or lakes. Today, we see only 15 percent coming from flowing water. This is quite a turnaround from 1966 and 1967.

Concerning scientific collecting of mussels in lakes, let me make a few suggestions. In still water (lakes) you should collect specimens by hand; in a lake the organisms are facing in all directions. Therefore, if you drag a brail through these areas there is a good chance that you will collect nothing. However, in an area with current, all of the mussels will be facing into the current to feed, and you will be more successful with the brail. If you use a brail in still water, you might collect an occasional mussel, but this will not be representative of the area.

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* President, American Shell Company, Knoxville, Tenn.

Brailing should be used primarily to indicate whether or not a particular species can be found. There are simply too many variables to consider the use of a brail for accurate collecting of all species in an area. For example, if a towboat has gone by, all of the clams could be closed. The size of wire used to make the brail hooks may not be the right size to collect all species in an area. Obviously, if the shells are closed for any reason, you will not catch anything using a brail. We have noticed an interesting problem in the Ohio River where the water is quite shallow. In the spring, when the mussels are spawning, quite a number can be harvested using a brail; however, later in the season when the water gets warm, the shells close and it is difficult to collect clams using the brail.

In Wheeler Reservoir, near Decatur, Alabama, in the still water, we found a place where about 100 tons of shells were collected in a small area of about 100 yd in radius. These shells included washboard, threeridge, pigtoe, and other species with some weighing up to 5 lb each and some of fantastic quality. Nearby, only in the main channel where there was current and with the water being much deeper, we found similar species; however, the quality was very poor and not suitable for commercial use.

I would like to comment about obtaining permits for harvesting mussels. Beginning at the Nasworthy Reservoir, near San Angelo, Texas, all the way to the eastern seaboard, you can find literally thousands of locations containing many different species of mussels. There are many people throughout this wide area that are interested in collecting mussel specimens. If a Federal permit is required by each collector, the Fish and Wildlife Service (FWS) could not handle the paperwork. Even with the present work load, the FWS is having difficulty in handling the permit requests. In my opinion, the issuing of licenses for the taking of mussels should continue as it is now, with the state issuing mussel permits.

I have another recommendation that I would like to make to the FWS people. The FWS people should survey a broad spectrum of knowledge before coming up with a decision on endangered species. It is wrong to make decisions that are not based on sound knowledge and investigation. I believe this has happened several times. Let me describe a problem that relates to this. The American Shell Company also deals with wild and cultivated ginseng. I would like to wager that no one in the FWS in Washington can distinguish between these two types of plants. This is unfortunate, but it is one of the problems that we are facing. We question the unreasonableness of American ginseng being on Appendix 2 of the Endangered Species Act since American ginseng can be planted in the wild or domestically cultivated. Further, no one in the FWS in Washington knows why the American ginseng was placed on the endangered species list.

We have never been contacted by the FWS concerning the freshwater mussels. However, my company has information which might be of interest from an endangered species standpoint. I would like to offer data that

we have on mussels to the Waterways Experiment Station (WES) for future use by Districts. Each year we survey at least 100 to 150 new locations looking for commercially valuable mussels. Out of this number, we may find 3 or 4 sites that are suitable for commercial harvest. The other sites might support tremendous numbers of shells which have no interest to us. After having gone to the expense of hiring a diver to obtain these data, it would not be much of a problem to supply information on these particular areas to WES.

Speaking for my company and our associates (perhaps hundreds of people in various states), we are willing to cooperate. We are interested in mussels and certainly do not want to see any of these species become extinct. Realize that many people in the commercial clamming industry are afraid that if they provide information on endangered species, the Government might come in and close down their form of livelihood. Along these lines, let me mention a situation that happened in Tennessee in 1980. The Tennessee Game and Fish Commission was under considerable pressure to close an area near Hartsville, Tenn., on the Cumberland River. This area contained a large number of species of shell, with a large percentage being Washboard, but included a small percentage of endangered species. I predict that within three to five years the endangered species of mussels they were trying to protect will be lost due to increased sedimentation caused by snags such as logs, tree tops, etc. In the past, the few brailers that operated in these areas kept these beds of mussels clear of snags. The endangered species in this area depends on free flowing current for survival. In my opinion, the Washboard will thrive and the endangered species will be lost as a result of this area being closed.

At the present time, collecting shells in Kansas is quite easy because of the drought in Grouse Creek near Winfield, Kansas. There are thousands of shell of many different species, some possibly endangered, just lying on the banks where the water has receded. Although this is a terrible thing from the standpoint of the resource, situations such as this provide useful information about the location, size, and the species composition of mussel beds.

Commercial fishermen usually pick up an occasional mussel on a troutline or fish net, and they can usually tell you where mussel beds can be found. Another source of information is the rescue squads that have diving units. These people retrieve bodies and automobiles from water, and they can very often provide information on the location of mussel beds. They also use grab hooks while searching for bodies, sometimes covering very large areas of water. These grab hooks occasionally pick up mussels.

Let me stop now and let you people ask questions or make comments.

Discussion

A. Miller: Describe how shells are processed for commercial use.

J. Peach: The shells are normally harvested alive with the animal still inside. The mussels are placed in a vat containing water and steamed until the shell opens. We usually steam up to 3 tons of mussels at a time. The mussels are then put into a revolving tumbler which knocks the meat out of the shell. Next, these shells go to a conveyor belt where they are sorted and loaded into bags. The bags hold from 175-200 lb of dry shell. The bags are loaded into large containers and taken to Mobile, Alabama, New Orleans, Louisiana, or Houston, Texas, where the containers are loaded onto railcars and transported to Los Angeles or Oakland, California. From there they go by ship, usually to Japan. The importers then distribute the shells to firms that process this material into beads to be used for cultured pearl production. Each shell is processed in the following manner: The hinge and thinner areas of the shell are cut away and discarded. Next, the shell is cut into thin slices. These slices are then cut into cubes which are fed into a tumbler. The tumbler produces a fairly oval bead. Finally, these oval shaped beads are placed in a pressure grinder which produces a perfectly shaped sphere with a marble-like finish. These spheres are sorted for color and quality and sold for use in the cultivation of pearls. Most of the cut pearls are produced in southern and central Japan with a few in Australia and other South Sea Islands. These polished beads are planted in the pearl oyster where they are left for 12-24 months. What is particularly interesting about this is that 85-90 percent of the weight of the cultured pearl is actually a pearly mussel from the United States. When you wear a cultured pearl you are basically wearing a domestic product.

G. Buglewicz: Describe the activities of a commercial shell harvester. Is this a seasonal job?

J. Peach: The harvest of mussel shell is basically a seasonal operation, especially in northern and central states. The shells are harvested by diving, hand picking, and brailing, with brailing accounting for only a small percentage of the production and the largest percentage of production being produced by divers. The picking is normaliy done in shallow water without the use of diving gear.

J. Kessler: How much are commercial shells worth a ton?

J. Peach: Depending on their quality we pay anywhere from $300 to $1200 a ton.

P. Yokley: Are the divers able to select the type of shells they want when they work an area?

J. Peach: The divers are very selective. They collect mostly the larger shells. When they are down, they cannot afford to waste time with small shells since they possess no commercial value and require more effort to dislodge from the bottom. By feeling the outside of the shell, a diver can determine if the shell is commercially valuable or not.

P. Yokley: How about the ebony shell? Does this shell have commercial value?

J. Peach: The ebony shell is difficult to harvest by divers because it is usually imbedded in the bottom. Most ebony shells are harvested by brailing; however, this species is of less interest for commercial use because the surface of the shell has a very lustrous finish that creates what we call a fish eye effect and results in a second grade bead.

D. Nelson: Do commercial clammers belong to some type of organization? Could we get a list of the commercial clammers?

J. Peach: There is an organization called the Natural Products Harvesters, Inc., in the state of Tennessee; however, the best method to obtain a list of these harvesters would be by contacting state licensing agencies and obtaining names and addresses of those persons having a mussel license. I can provide you with a list of states that would have this information available.

G. Buglewicz: Do all harvesters have to get a permit to collect clams?

J. Peach: Yes.

J. Williams: Has anyone tried to find a use for the meat from a mollusk?

J. Peach: Yes. We have been cooperating with the University of Tennessee (UT) for about 12 months on a project with the Giant Washboard. This project involves studying the washboard mussels from the Tennessee River system, and the Cumberland River system, and is being headed by Dr. Jaynes of UT and on which a report will be issued soon.

J. Williams: Is this for human consumption?

J. Peach: Yes. The purpose of the study is to determine the suitability of the meat as a food source. Initial reports indicate that it is suitable once cooked.

J. Willaims: I have eaten chowder made from Tombigbee River mollusks and found it to be really good.

J. Bushman: What was responsible for the drastic reduction in the amount of shells being exported from 1966 to 1980?

J. Peach: First of all, 1966 was a peak year. However, let me expand and clarify this a little, Today 4,700 tons are probably equivalent to 10,000 tons back in those days. These shells collected today from lakes are healthier and the yield of material is better, even though the total tonnage may be less.

A. Clarke: Once overharvesting cuts down the number of clams populating an area, how long is it before the number recovers? Perhaps this is a loaded question but I have heard that clamming in the Ohio River is pretty heavy which has caused the beds to become quite sparse.

J. Peach: This depends on the area involved, but let me discuss the Ohio River situations first. Although there is a tremendous quantity of shells there, we have not had much interest in these shells. This is because about the only time you can catch mussels in the Ohio River is in the spring. The cost of setting up a brail boat now is prohibitively expensive if you work only 1-1/2 months a year. There is very little interest in Ohio River shells except for the lower part of the river below Caving Rock, Kentucky, down to Cairo, Illinois. In my opinion, the Ohio River has a tremendous population of shell and is not in any way suffering from being overworked. However, lake mussels grow rapidly; in 5 years, you can have a large healthy shell that is suitable for commercial use. For example, Fort Gibson Lake, a Corps lake outside of Tulsa, Oklahoma, is probably one of the most prolific lakes I have ever seen. It has literally millions and millions of small shells of different species that grow very fast. Since 1976, over 4,500 tons have been taken from Fort Gibson Lake. In my opinion, lakes hold up better to harvesting than do moving streams. Now take the case of the Giant Washboard, a very widely distributed species. In a bed of these, that is an area where a lot of shells have accumulated together, the divers can harvest a large percentage of the shells in a given bed primarily because the size makes for easy harvest. But, even in the case of the Washboard a diver can never harvest all of the shell since he is working in zero visibility water.

E. Cawley: What controls the amount of harvest? Do you stop buying shells after a period of time because a foreign market is saturated?

J. Peach: At this time two companies control practically all the production of shells. I anticipate that in the near future there will be an oversupply of shells because of the large numbers of impounded areas that are very prolific in the production of mussels.

J. Bushman: Are these lakes with good shells natural or artificial lakes?

J. Peach: These are impounded (not natural) lakes.

M. Cooper: After you work a bed, how long is it before you can rework it, or do you actually rework the mussel beds?

J. Peach: Suppose you find a good area for mussels. Automatically a lot of people are interested in working there and harvesting mussels. After a while it reaches a point where the yield drops and a lot of the people quit. Finally, only a few people still work the area, but recovery time depends on whether or not you are working a lake or a stream. In Kentucky Lake or Fort Gibson Lake, two of the largest producing lakes that I know, you should have a large population of shells within 5 years after a heavy harvest. However, flowing streams recover more slowly.

M. Cooper: To what extent have you reworked areas to back up that statement?

J. Peach: Extensively.

M. Cooper: You have actually gone in after 5 years and reworked areas?

J. Peach: Yes. Realize that there are a lot of shells in this country. Few people are aware of the quantity of shells that are in this country. I hope that this meeting will help enlighten a lot of people concerning the mussel population. Let me make another point at this time. How many agencies would fund an operation that has approximately 150 divers working in a variety of places? The cost could be prohibitive. However, unless it is storming, we have at least 150 divers working across the country.

T. Strekal: Are all these people employed by your company?

J. Peach: Actually they are private contractors. We lease equipment and they in turn agree to sell shells to us. They are not actually our employees.

E. Cawley: Do old reservoirs appear to have more value for commercial shells than new ones or is there any pattern?

J. Peach: Reservoirs 20 years and older tend to become very productive. Lakes less than 20 years old tend to be less productive. However, I should point out that some lakes, for various reasons, may not have any shell at all. As you know, this country has a tremendous number of impounded lakes and a large percentage of these lakes have a population of shells, with the population of the lakes varying according to the age of the lake.

A. Clarke: Has *Corbicula* affected your business? Do you think they cut down on the population of clams? Do they clog the brail hooks?

J. Peach: One reason we use a nine- or ten-gage wire is to keep *Corbicula* off the hook. We have noticed areas where the concentration of *Corbicula* was so great that we suspected that it had a detrimental effect on the mussels. I noticed this particularly near Decatur, Alabama, where there was a high concentration of *Corbicula* and a low concentration of mussels.

D. Nelson: When you are in a new area looking for mussels, what sort of criteria do you have for finding beds? Are there any noticable trends?

J. Peach: We study maps and know the areas that produced mussels in the past. We are aware of the characteristics of the different drainage systems and this helps us also. If rivers have sand that shifts drastically, we know that this will not support commercial quantities of shell. If the water level of lakes fluctuates too much, this also may be a factor causing shells not to be present in commercial quantities. Heavily polluted areas such as streams below large cities normally do not produce commercial quantities of shell.

J. Jenkinson: Would you comment about the native pearl culture business in this country?

J. Peach: My company and another is currently involved with pilot studies for growing nonnucleated and, to a lesser extent, nucleated pearls. We plan to become involved with aquaculture, primarily with the thin type of mussel. My projection, based on what I know of the Chinese and Japanese pearl industry, is that this will be a phenomenal business in this country. Aquaculture may provide the scientific community with a lot of valuable information such as how to cultivate endangered species of mussels.

M. Cooper: Has the species of commercial interest changed over the past years?

J. Peach: At one time the Washboard was unsellable but now this shell makes up the bulk of the export market. There have been changes in the species of commercial interest.

T. Strekal: Why is that?

J. Peach: Because of the high quality of the Giant Washboard, Threeridge, and Maple leaf growing in lakes.

B. Buselmeir: Of these 100-150 surveys done by your company for shells, are those done mostly in lakes by divers? Since the potential for shells is better in lakes than in rivers, does this tend to bias your surveys?

J. Peach: We sample all types of freshwater environments. Although we do a tremendous amount of checking in rivers, in recent times we have worked more in lakes since this is where we get a high quality shell.

H. Murray: You mentioned the quality of shell. Clarify what you mean by quality. Do you mean luster, character, density, hardness, or softness?

J. Peach: A very solid shell that is free of organic wax layers, brittleness, imperfections, and natural lines. Also we avoid what we call fish eyes or bright spots which are caused by some shell layers being brighter than others.

E. Cawley: Please comment on the diving equipment used. Do you have preferences?

J. Peach: Let me clarify a point. The equipment we lease might consist of an outboard motor and a boat. We do not lease the diving equipment itself, although we might make recommendations. Generally we do not use hard-hat divers, although this is an effective method. Most divers use SCUBA gear with surface supplied air or high pressure diving tanks.

DISCUSSION GROUPS

Introduction

On the second day of the workshop, after most of the presentations had been made, all participants divided into groups for a brief discussion period. The groups were based upon the background and expertise of the attendees. The first group consisted of individuals from universities and colleges. The second consisted of personnel from Corps of Engineers District/Division Offices. The third group consisted of any attendee who did not fit into the above groups. Represented in this discussion group were people from the U. S. Fish and Wildlife Service, the Tennessee Valley Authority, consulting firms, the Jackson Museum of Natural Science, and the American Shell Company.

The purpose of these subgroups was to allow workshop attendees to express their opinions on any aspect of the workshop and/or the technical presentation. As an aid to stimulating discussion, a series of questions (see below) were distributed to all the subgroups. It was not intended that only the written questions should be considered; attendees were encouraged to bring forth any comments they felt were significant.

The following summaries, provided by the subgroup leaders, are syntheses of the discussions which took place during approximately 45 minutes on the morning of 20 May 1981. The subgroup leaders and others felt that there was not enough time to fully elaborate on all the important issues; however, as the following papers demonstrate, interesting comments were voiced during these meetings.

Discussion Questions

1. Should there be another Endangered Mollusks Workshop? Suggest topics and speakers. Was the presented information too technical?

2. Within the stated objectives, suggest additional aspects or strengthening for the two-year Endangered Mollusks Study and the gravel bar project.

3. Based on your experiences and this meeting, suggest some concise, specific research tasks which should be conducted by WES. These should be related to the Endangered Species problem but not covered by any ongoing WES study.

4. The current approach to Endangered Mollusks Work is to have District Biologists conduct/contract a field study for bivalves and then coordinate the results with the U. S. Fish and Wildlife Service. Does

this protect the resource or are we simply covering our tracks? Suggest improvements.

5. Jim Williams and Paul Hartfield illustrated the value of museums in research with mollusks. Suggest several mechanisms whereby Federal Agencies could coordinate with and/or provide curatorial support for museums. How could this be implemented?

6. Comment on the objectives of the Bivalve Recovery Team. How could their approach be strengthened or expanded to help protect Endangered Mollusks?

7. This meeting has brought forth the need to open the lines of communication among Federal and state agencies, the academic community, and local and private interests. Suggest several mechanisms to further this communication.

8. What are some very significant research needs for Freshwater Mollusks? For example, should future studies be directed towards habitat requirements, distribution, or taxonomy?

9. Suggest research projects that would help to resolve the problem of speciation in freshwater bivalves.

10. Suggest mechanisms to involve the commercial shell industry with information needs of Federal Biologists.

11. Provide additional comments or suggestions, etc., concerning this meeting or the research project.

The Academic Community

by

Paul Yokley, Jr.*

The Freshwater Mollusk Workshop was informative for all who attended. It was a first in that it integrated Federal and state agencies and academic as well as private interests.

Future workshops could be useful and should include information about anatomy and physiology of freshwater mussels. Very few people appear to understand the very basic requirements of mussels. Almost no details exist concerning the specific requirements of the rare species. The spawning habits, host specificity, and basic needs of each species should be studied before we can transplant and provide successful recruitment habitats for them.

The presentations at this workshop were needed and provided basic information for all. Future workshops would extend the knowledge of those participating and could deal with specific mussel species and their basic structure and environment.

One deficiency of the gravel bar project is that it encompasses only the survival of adult mussels and has no provisions for monitoring the successful propagation of transplanted species.

Silt and substrate quality are specific factors affecting the juveniles of site-sensitive mussels. What are the ranges of limits of these physical and chemical factors?

Too much of our money and research is spent to get a quick solution to the existing problem. The moment the U. S. Fish and Wildlife Service accepts the results of a short study, the Corps of Engineers ceases further research until the pressure is applied again. These short-term efforts relieve the pressure for a moment but do not solve the basic problems. Also, they probably cost more than a continuously supported, long-term study.

Life cycle studies of mussels cannot be done in short interrupted attempts. These require physical equipment and long-term efforts by well-trained malacologists. A malacologist must be trained (experienced) in ecology, ichthyology, taxomony, and anatomy before attempting to work with life cycles and before predicting the fate of a mussel species.

Much effort is going into the taxonomic area of mussel research. More should go into the ecology and life cycle areas to successfully protect rare species. We cannot train everyone to identify all mussel species any more than we can train everyone to identify all fishes,

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* Professor of Biology, University of North Alabama, Florence, Ala.

birds, amphibians, or any other group. We must call upon the experts to do the job.

Federal agencies should cooperate by funding regional curatorial work on a continuing basis. The American Society of Systematists could provide some information on this.

The bivalve recovery team appears to be working mainly with adult *Lampsilis higginsi* survival and should become more involved with fish host relationships.

Collecting, identifying, and life history studies of mussels should be a concern of all groups but the work must be done by those best trained in the field.

The Tennessee-Tombigbee Waterway could never be completed if the Congress funded it for 90 days, then stopped, then funded it for another brief period one year or so later. Freshwater mussel research requires an extended view of the entire system which should be outlined and then supported continuously while the problems are being solved.

Corps of Engineers

by

Eugene Buglewicz*

Group B, composed of representatives of Corps of Engineers District and Division Offices, met in *Open Session* on 20 May 1981 to discuss questions provided by the workshop chairman. The following questions were discussed:

Question 1

Should there be another Endangered Mollusk Workshop? Suggest topics and speakers. Was the information presented too technical? There was unanimous agreement that another workshop on endangered mollusks should be held. Timing of the workshop should coincide with the end of the Endangered Mollusk Study and/or tentative findings of the Gravel Bar Studies.

Because of the diversity of Corps of Engineers requirements for endangered species information and the varied backgrounds of Corps of Engineers biologists, some vehicle for providing background information on mollusks was recommended to bring participants up to a predetermined level of understanding of the species and associated problems. Several methods were recommended:

a. Forward a list of references to workshop representatives for reading prior to attendance.

b. Prepare summary document and forward to each participant prior to the workshop.

c. Present a general discussion of the biology of mollusks during one of the first sessions of the workshop.

Preinformation materials or briefings should include a historical perspective on the organism, biology, physiology, and taxonomic features, including comparative taxonomy, key literature summaries and sources of information, and a review of the economic status of the organism.

Ms. M. Cooper, South Atlantic Division, recommended that the next workshop be a problem-oriented workshop. Potential participants would be forwarded preworkshop letters requesting problem statements. The workshop sponsor would consolidate the problem statements and prepare the workshop agenda to fit the needs and interests of the respondents.

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* Limnologist, U. S. Army Engineer Division, Lower Mississippi Valley Division, Vicksburg, Miss. 39180.

Questions 2 and 3

Within the stated objectives, suggest additional aspects or strengthening for the two-year Endangered Mollusk Study and the Gravel Bar Study.

Based on your experiences and this meeting suggest some concise, specific research tasks which should be conducted by WES. These should be related to the Endangered Species problems but not covered by any on-going WES study.

These two questions were considered together because of the information required by each, their relationship to the Endangered Mollusk Study, and the Gravel Bar Study and specific needs of District/Division Offices identified during the discussions. The Endangered Mollusk Study was seen as a valuable aid to the identification of endangered molluscan species, although there was some apprehension expressed that such a document in inexperienced hands could result in misidentification of endangered species and cause problems for District projects.

It was suggested that where available, each organism's habitat requirements be included, and that pertinent literature and summaries be included either as a companion document or in the proposed manual. It was agreed that the document would be more useful to District biologists since it was to be in looseleaf form. This will simplify changes to the document and provide for inserting field notes or other pertinent information on any species. The final document should include sampling procedures and survey cost summaries for District use.

The experimental gravel bar investigation should emphasize quantifications of physical hydrological parameters in order to better delineate the relationship of molluscan species to their habitat. Other aquatic life inhabiting the gravel bars should be identified and quantified, and the relationship of other habitats which could influence gravel bar species should be documented. Finally, it was suggested that improvement and evaluation of sampling techniques, within the framework of the experimental gravel bar study, could be undertaken concurrent with and complementary to the primary purpose of the investigation.

Other Comments

Other information pertinent to the workshop was brought out during the discussion of questions 1-3 but did not specifically relate to these questions. These items are summarized below:

a. The participation by Mr. J. L. Peach of the American Shell Company in the workshop provided an invaluable perspective of molluscan utilization.

b. Since the primary purpose of the workshop is to provide and receive information, more agenda time for structured open discussion, both inter- and intra-agency, should be provided.

c. Basic life requirements for molluscan species, including endangered species, are not well known. Quantified habitat descriptions, such as current velocity and sediment type using appropriate field and laboratory standardized procedures, must be included in molluscan surveys.

d. Life history information for molluscan species is not available.

e. The ecological niche occupied by mollusks and their contribution to the aquatic habitat's productivity are not understood. Most information on mollusks is survey data. There is a need to identify the role mollusks play in the aquatic environment and their interaction with other members of the aquatic community.

f. The use of museums for archiving organisms collected during field projects was seen as a cost-effective method for maintaining species collected during field projects. Museum collections could be used to verify species collected by District offices and to assist in describing the distribution of organisms within District boundaries.

Corps District/Division Personnel

by

Robert Buselmeier*

Our group felt that there was not enough time to adequately discuss the topics presented at the workshop. It is frustrating to have subgroup meetings cut short and time for questions and answers following an oral presentation limited so severely. One possible solution would be to increase the total length of the workshop to about four days to accommodate all activities.

The information presented was not overly technical. However, it would have helped if there was a preliminary "get-acquainted-with-endangered-mollusks" introductory session prior to the formal meeting. The workshop might have benefited by having all participants at the same level of knowledge before formal presentations began. Since most participants arrived the day before the workshop, the introductory material (consisting of slides, movies, and exhibits) could have been presented during this first evening. Then, since presentations covering equipment, field techniques, associated problems, ecological factors would have been presented early, more formal workshop time could have been devoted to in-depth presentation and discussions. This would also eliminate the need for taking workshop time during the day for examining gear and exhibits.

It was suggested during our subgroup meeting that all participants would benefit from distribution of study materials (by mail) prior to attending the meeting. While many individuals, myself included, would have difficulty finding time to review these materials, on the whole they could be helpful.

Concerning the WES gravel bar project, it is my feeling that it should be conducted as much as possible, using techniques, manpower levels, etc. that are readily adaptable by District personnel who must operate under limited time and budgets. In addition it should be understood that many Corps personnel are inexperienced in these areas. It should be kept in mind that unexpected problems continually creep into virtually all of our projects; many times District people feel that WES is unaware of some of their "practical" problems.

Concerning the WES field manual to Endangered Mollusks, such a guide will be more useful if it is loose-leaf and water resistant. It could be supplemented from time to time by contributions from others offering tips for fieldwork and species identification.

Some suggestions for future WES research include:

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a. Design stream flow structures for gravel bar development and for habitat improvement for endangered mollusks.

b. Investigation of (substitute) alternate hosts for glochidea of endangered mollusks.

c. Improved sampling equipment and techniques for endangered mollusks.

d. If appropriate, develop a national directory of malacologists, private museums with mollusk collections, and others with expertise in the field. This would greatly facilitate District coordination concerning endangered species problems.

For this workshop, the subgroups were organized based on similarity of background and interests. However, in the future it might be wise to mix everyone up to achieve a diversity of backgrounds in each subgroup. This should provide at least two benefits: (a) a concensus that is more representative of the real world and (b) a full understanding of each other's viewpoint.

Concerning the talk by Dr. Stern, there was one very significant point, I believe. Success of such a venture depends upon the knowledge and experience of its members, not necessarily on the academic background or education (i.e. at least one representative from Government, academia, etc.) of its members.

In conclusion, I feel it was an excellent workshop and most who attended would probably like to come if another meeting is held. Although the time was short, much was accomplished in two days. Finally, many who attended appreciate the efforts made by WES to find travel monies for those Districts which could not afford to send representatives on their own.

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Other Agencies, Federal and Non-Federal

by

John J. Pulliam III*

Our discussion group consisted of representatives from the U. S. Fish and Wildlife Service (FWS), the Tennessee Valley Authority (TVA), consulting firms (Dames and Moore, ECOSEARCH, Inc.), the Mississippi Museum of Natural Science, and the American Shell Company, Knoxville, Tenn. We felt that the workshop was valuable and had a good mixture of attendees. Another workshop would be welcomed with presentations consisting of a mixture of both technical and general presentations. However, these workshops should not be a forum for extremely technical discussions. The next meeting should center around common problems and methods available to solve those problems.

Several participants in the discussion group voiced the opinion that research should be directed towards a unified and not a piecemeal approach. This would be preferable to having one person studying habitat requirements, another involved with life cycles, and someone else working distribution or taxonomic problems. It was also suggested that more emphasis should be placed on protecting endangered ecosystems rather than individual endangered species. Another comment expressed concerned involvement of the commercial and private sector on problems dealing with endangered species. It was felt that these groups should be contacted during status reviews and their information on sampling, distribution, and abundance of species should be considered.

There were several suggestions for providing curatorial support to assist museums in cataloging and maintaining collections. Interest in this topic was based on comments made by Mr. Paul Hartfield (Mississippi Museum of Natural Science) and Dr. Jim Williams (Office of Endangered Species, FWS) during their presentations on 19 May 1981. Suggestions included:

a. Fund a series of regional museums.

b. Stipulate where specimens should be deposited and provide monetary reimbursement for any contracts which require the collection of voucher specimens.

c. Individual agencies could establish and support their own museums.

Finally, it should be made clear that the main objective with this legislation is to protect the resource. To accomplish this we must ignore the so-called program boundaries and work together to form a

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unified effort. We must not rely on others to do the work, but all interested parties should participate to develop research needs, appropriate methods, needed information, and funding requirements.

OBSERVATIONS/CONCLUDING REMARKS

by

John Bushman*

Let me state that the prime purpose for holding this workshop is to provide assistance to the U. S. Army Corps of Engineers District personnel. Information developed during these last two days will aid District people in complying with the various environmental regulations and requirements that recent legislation has placed upon them. At this meeting we have had the good fortune of bringing together experts from the Federal government, the academic community, several museums of natural history, and the commercial clamming industry.

You are all aware that the focal point of concern for the last two days is with the Endangered Species Act of 1973 as amended. When Federal funds are used to construct or modify a water resource project, we must be certain that endangered species are not negatively impacted. Also, the Corps of Engineers is involved with regulating activities that take place in waterways. This usually involves placement of fill and/or removal of material from a stream or a river bottom. Obviously, those in our agency who regulate these actions are concerned with endangered species. Districts in the central and eastern United States are particularly involved with these problems. This is because of the nature of the work that they are involved with and, of course, the distribution of the endangered mollusks.

One of our primary interests in the development of this two-year study was to provide District people with technical information pertaining to the mollusks. A handbook with technical notes concerning the best methods for the collection, safe handling, and the identification of these species will go a long way toward achieving this need. The information that WES is providing will not answer all the questions, but it will provide an important starting point. A District biologist in a particular locality may find that certain procedures or information developed by WES may need modification but at least he has received the benefit of technical expertise developed during this study.

Concerning this workshop, not only do we have a diversity of backgrounds in attendance but also a broad range of expertise. There are some individuals here who have spent most or all of their professional careers studying mollusks. On the other hand, some of the participants have a limited knowledge of these organisms, perhaps their training was in another area, and recent concern over these organisms has motivated them to develop new expertise. This meeting has given everyone an opportunity to discuss problems encountered by the amateurs, the academicians, and the resource managers who have specific responsibility in this area.

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I have noted that the attendees at this workshop fall into four groups. The first are those whose responsibility is to administer the statutory requirements of the endangered species legislation. Obviously, the Fish and Wildlife Service personnel fit into this category. The next group are those who must work within the confines of the Federal legislation to accomplish certain tasks. The Corps of Engineers people make up the bulk of this group, but included with them are the professional consulting firms and other Government agencies such as the Tennessee Valley Authority. The third group, those from the universities and museums, have conducted much of the basic research on the mollusks. Finally, the commercial shell industry, which has an economic interest in this resource, is represented at this meeting.

I believe that a combined, coordinated effort among all the concerned parties is a very effective way to deal with problems associated with freshwater mussels. We must communicate among ourselves and understand one another if we are to manage and conserve this resource. This workshop has provided many viewpoints on various aspects of selected problems associated with distribution, sampling, and identification of bivalves. It is apparent that in the last three or four years great strides have been made in some of these areas; however, we still have a long way to go.

These are times when monies spent by Federal agencies are questioned closely. If the Corps of Engineers studies fish, someone from the Office of Budget and Management asks, "Why fish? Isn't that another agency's responsibility?" or "Why does the Corps of Engineers study water quality? Is that not the responsibility of the Environmental Protection Agency?" Certainly we must ensure that there is no duplication of effort in these areas. However, as this meeting has demonstrated, the question of habitat requirements concerning the freshwater mussels touches on these and many other disciplines. We must be knowledgeable concerning each other's involvement in these various research areas. When all concerned parties communicate, research funds are used wisely and efficiently.

Finally, let me say that another endangered mollusks workshop will be extremely beneficial to the Corps of Engineers personnel and others as well. This would provide an additional forum for discussing and analyzing current knowledge and to identify areas where future research is needed. I am sure that you all agree that this meeting has been informative. We have had good questions and candid statements expressed on a high plane. We must continue in this direction to get the job done without becoming embroiled in personalities, policies, and politics. Thank you.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Freshwater Mollusks Workshop (1981 : Vicksburg, Mississippi)
Report of Freshwater Mollusks Workshop, 19-20 May 1981 / by Andrew C. Miller, Compiler. -- Vicksburg, Miss. : U.S. Army Engineer Waterways Experiment Station ; Springfield, Va. : available from NTIS, 1982.
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1. Environmental impact analysis. 2. Mollusks. 3. Rare animals. I. Miller, Andrew C. II. United States. Army. Corps of Engineers. Office of the Chief of Engineers. III. U.S. Army Engineer Waterways Experiment Station.
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